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BUREAU OF PUBLIC ROADS

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A JOURNAL OF HIGHWAY RESEARCH

U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS

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THE CONNECTICUT TRANSPORTATION SURVEY

DIGEST OF THE REPORT OF A SURVEY OF TRANSPORTATION ON THE STATE HIGHWAY SYSTEM OF CONNECTICUT [1]

CONNECTICUT was one of the first States to adopt the principle of State aid in highway construction. Its highway department was created in 1895 for the purpose of administering the State-aid appropriations. It was also one of the first to establish a definite system of connected trunk-line highways for construction and maintenance under the complete control of the State agency. This was in 1913 and with subsequent additions the system in 1923 embraced 1,566 miles, of which 1,114 miles were improved. By successive amendments of the law the State department has also exercised an increasing degree of control over the State-aid roads, and at present there is little to distinguish the State-aid roads from the trunk-line highways with respect to the State's participation in their improvement except that a portion of the cost of constructing the former is paid by local government units.

By 1923, when this study was made, the length of improved roads in the State highway system had grown to 1,780 miles and the amount of improvement better than macadam had increased to more than 480 miles. This improvement had been made with always inadequate revenues in the face of a constantly increasing traffic; the motor vehicle registration having increased from 23,200 in 1913 to 218,489 in 1924, an increase of 842 per cent. Its experience in this respect has been much the same as that of other States; but, because of its small area and its location between New York, Massachusetts, and Rhode Island, it has had to provide, on its main roads, highway service for a large traffic from adjacent States.

Although the State has been considered among the leaders in highway progress it was found that it was by no means keeping pace with the increase in traffic due principally to financial limitations. Old roads have been widened and strengthened, maintained to the limit of their serviceable life, and replaced as rapidly as possible with more adequate surfaces. In many cases the effort to prolong the life of the older roads beyond their economic life has resulted in heavy expense, yet limited funds permitted no other course. The same limitation is responsible for the fact that there remain on some of the most important roads sections of considerable length in the aggregate which are entirely inadequate for the present traffic.

Prior to 1923 it became evident that a large mileage of old road must be reconstructed, much of it involving widening of the road surface and improvement of the alignment which was designed to meet the needs of traffic of an earlier period. In addition to this a considerable mileage of new improvement was already needed and it was realized that still more would be needed to accommodate the rapidly increasing traffic. It was for the purpose of ascertaining the facts necessary as a basis for the framing of a program to meet these needs that the Connecticut highway transportation survey was undertaken jointly by the Bureau of Public Roads and the State highway department.

PURPOSE AND METHODS OF THE SURVEY

The general purpose of the survey was to obtain the traffic information necessary for the establishment of a definite plan of highway improvement based on the present and expected future traffic.

A classification of all highways on the basis of their relative traffic importance was felt to be the first need. Such a classification is required to determine the order in which the highways should be improved and the distribution of construction and maintenance funds over the highway system.

The selection of the most economical type for each highway is the next step. Such a selection must be based not only upon the present and expected future traffic density but also upon the type of the traffic units. The more important considerations are: (1) The present and estimated future density of traffic; (2) the ratio of the number of trucks to the number of all vehicles; (3) the relative number of trucks of large, medium, and small capacities; and (4) the maximum wheel loads and the frequency of heavy gross loads and wheel loads.

The final selection of the type of surface depends also upon physical considerations such as topography, drainage, soil and subgrade conditions, availability and cost of materials, as well as upon traffic considerations.

In addition to these purposes it was also planned to determine the place of highway transportation in the transportation system as a whole, and to establish the principles which should form the basis for the coordination of highway transportation with other forms in order to develop as a whole the most efficient transportation system.

The survey was begun in September, 1922, and continued for one year, during which time traffic data were recorded at the 57 survey stations shown in Figure 1. These stations, carefully located and designated before the beginning of the survey, were operated on an average of once a month by "recording" parties which recorded all passenger-car information and the principal types of motor-truck information, with the exception of the weights of the vehicles. Nine hours constituted the length of each operation at a station; the actual hours, however, varied with each operation and ranged between 6 a. m. and 9 p. m. A sufficient number of night operations were made to enable the correction of all traffic counts to an average 24-hour day.

In addition to the operation by recording parties, 8 of the 57 stations were operated by a "weight" party, which recorded all motor-truck traffic information, including weights of vehicles. These eight stations were located at key points on the principal highways in different sections in order that practices in motor-truck loading in various parts of the State could be determined.

[1] The complete report of the survey undertaken jointly by the Bureau of Public Roads and the Connecticut State Highway Department has recently been issued. Copies may be obtained from the Bureau of Public Roads upon request as long as the free supply lasts or they may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 30 cents per copy.

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The average daily distribution of traffic on the important highways of Connecticut as developed by the survey is shown in Figure 2. It is evident that the routes connecting important centers of population and industry carry the heaviest traffic. The Boston Post Road from Greenwich to New Haven is the most important highway in the State and the same route from New Haven north to the Massachusetts line is almost of equal importance. In general, the traffic tends to vary directly with the population and industry served by the route and inversely as the distance from centers of population and industry.

With the exception of the route from Greenwich to Westerly, the general direction of the important traffic routes is north and south. Other east and west routes although of considerable importance are secondary to the north and south routes. The distribution of average daily truck traffic shown in Figure 3 is, in general, similar to the distribution of total traffic.

The width of the white space between the black lines of Figures 2 and 3 represents the average daily traffic throughout the year. But traffic varies greatly with the seasons of the year and the days of the week.

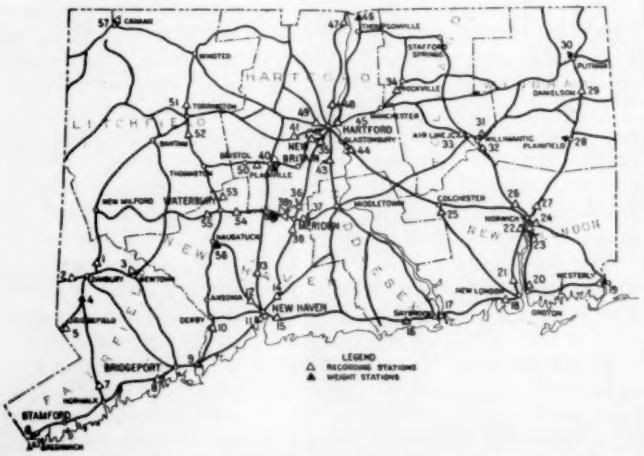


FIG 1.—MAP SHOWING LOCATION OF CONNECTICUT TRAFFIC SURVEY STATIONS

Hence there is also shown in these figures by the width from outside to outside of the bordering black lines the maximum traffic which occurs at all points at certain periods. Considering all types of vehicles, Sunday is the day and August the month of maximum total traffic. The distribution of the total traffic on a Sunday in August is therefore presented in Figure 2 as an indication of the maximum traffic density. The density of the traffic on this particular day was 254 per cent of the average.

Variation in truck traffic is considerably less than the variation in passenger-car traffic. The monthly variation in passenger-car traffic ranges from 29 to 193 per cent of the average. For truck traffic the corresponding range is from 68 to 122 per cent. Truck traffic is very uniform from Monday through Friday. On Saturday it is somewhat lower than on other week days, and on Sunday it is very low compared with other days of the week.

Maximum daily truck traffic, as shown in Figure 3, which represents a Friday in October, is approximately 146 per cent of the average daily truck traffic for the year. These figures represent the present normal peak load of traffic for which highway facilities are required. Unusual density of traffic on holidays or special movements on certain routes due to fairs, football games, and similar events will exceed in density the movements indicated on these charts. It is not necessary to consider these special movements in planning the highway program, but due allowance must be made for the expected increase in traffic during a reasonable period in the future.

In connection with the survey a map showing the distribution of population was prepared for comparison with the map showing the distribution of traffic. It is evident from this map that there is a relation between them. Of the 17 towns (the town in Connecticut corresponding roughly to the township in other States) having a population in 1920 of 640 or more per square mile, 16 are traversed by the seven routes which have been classified as the principal routes.

The areas adjacent to the principal routes are increasing in population at a more rapid rate than other sections of the State, the rate of increase varying from 17.2 to 39 per cent, whereas the rate of increase for the remainder of the State is only 4.7 per cent. The more rapid rate of population increase in the areas adjacent to the principal highways indicates the urgent need for the planning and construction of highways to serve future traffic needs in these areas.

The present distribution of population and the trends of population growth as reflected in the more rapid increase in the densely populated areas and the more rapid increase in urban than in rural population indicate that the present main traffic routes will continue to be the important routes and may increase in relative importance. The changes in relative importance of main traffic routes, as compared with those of secondary importance, must of necessity be slow and will not be important during the next few years.

The present trends indicate that minor traffic routes will with some exceptions continue to be of minor importance. The present areas of low population density and of decreasing or slowly increasing population will not become important traffic areas during the next decade.

MOTOR TRUCK CAPACITIES AND LOADING

The design of highways and the types of pavements to be selected are dependent not only upon the amount of traffic using them but also upon the type and weight of the traffic. The number of vehicles indicates the general importance of one route as compared with another and is the most important factor in considering highway width, parallel routes, and elimination of grade crossings and "bottle necks." But the determination of the amount of the traffic does not form sufficient or conclusive evidence for the final selection of highway design and type of pavement.

Analysis of traffic on the Connecticut roads reveals entirely different types of traffic on various highways. The first difference noted is a higher proportion of motor-truck traffic on one highway than another. This can be illustrated in the case of two highways, one of which connects two large industrial centers and the other a city and a pleasure resort. The latter highway would naturally be mainly a passenger-car route and be used less by motor-truck traffic (in proportion to total traffic) than the route connecting industrial

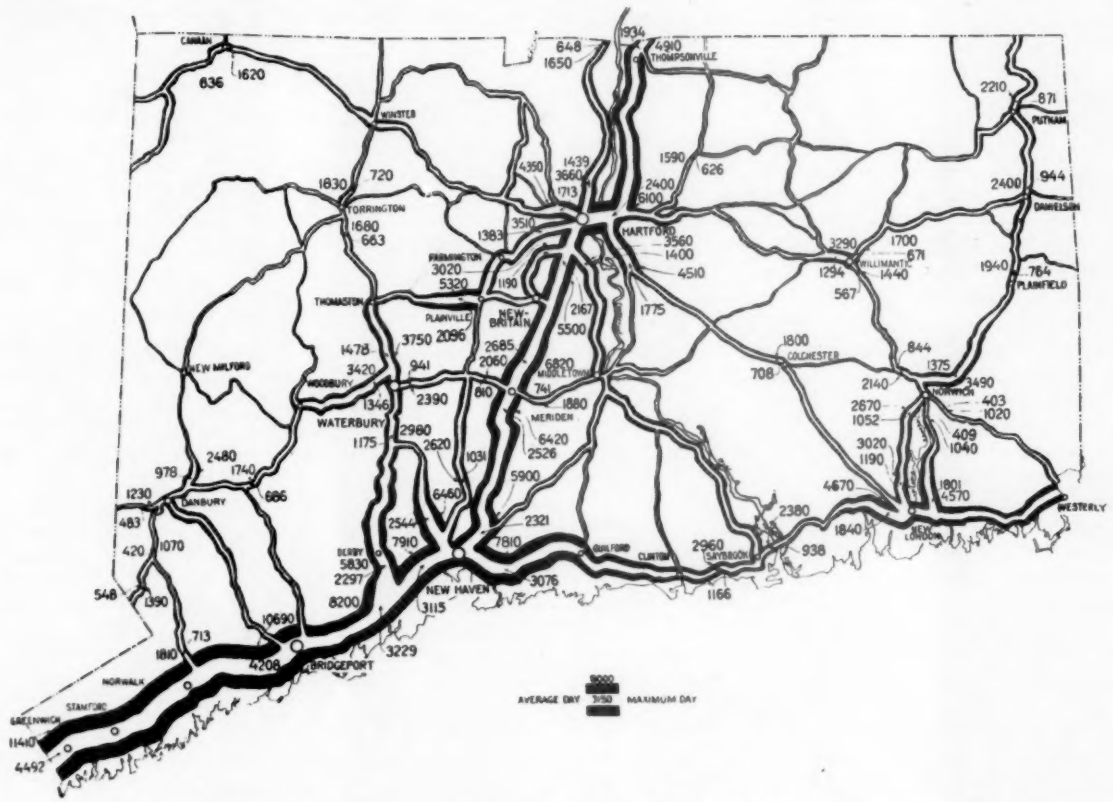


FIG. 2.—AVERAGE DAILY AND MAXIMUM MOTOR-VEHICLE TRAFFIC ON THE IMPORTANT HIGHWAYS OF CONNECTICUT

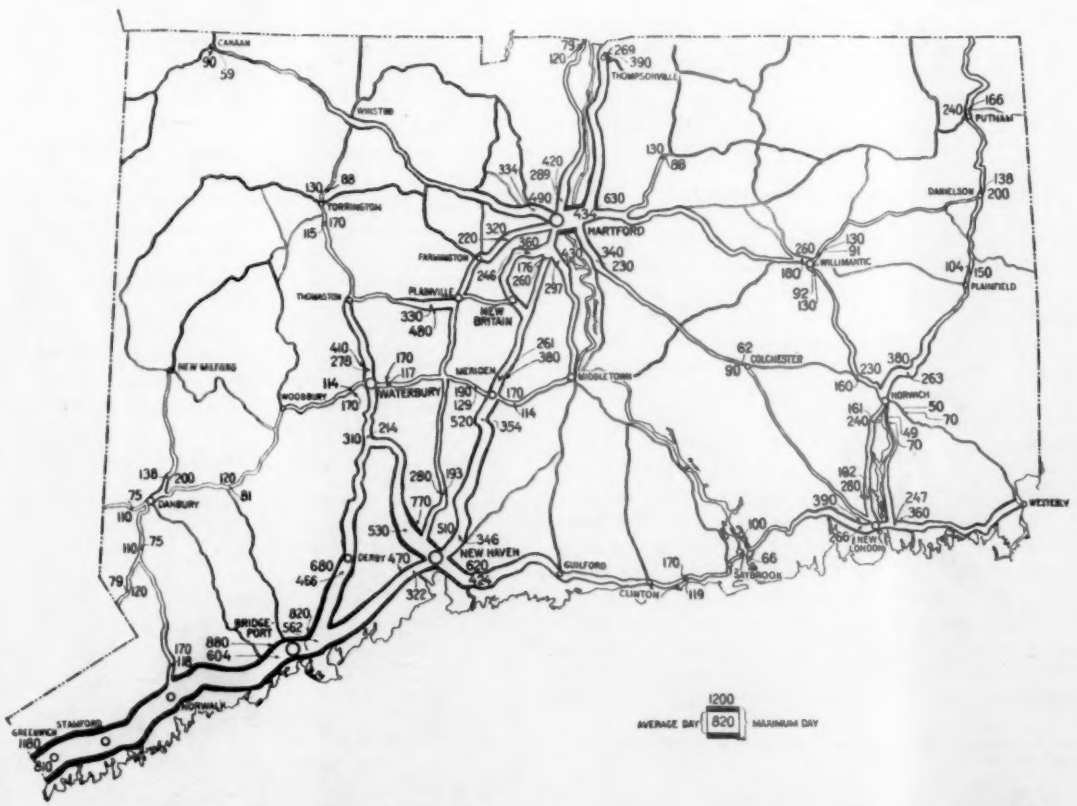


FIG. 3.—AVERAGE DAILY AND MAXIMUM MOTOR-TRUCK TRAFFIC ON THE IMPORTANT HIGHWAYS OF CONNECTICUT

centers. A more searching analysis reveals variation in motor-truck traffic itself; a preponderance of large-capacity trucks and heavy gross loads on one route and of small-capacity trucks and light gross loads on another.

Variation in the capacity, loading, and tire equipment of the vehicles causes corresponding variations in the effect upon the highways. Light, pneumatic-tired vehicles have less effect then heavy, solid-tired vehicles. An investigation by the Bureau of Public Roads into the effect of motor-truck impact upon highways, shows that a badly worn solid tire can deliver an impact seven times as great as the static wheel load. Pneumatic tires, on the other hand, seem to definitely limit the impact. In no case, using obstructions as high as 4 inches, has it been possible to record pressures under pneumatic tires greater than double the static weight.[2] In the choice of the design and type of pavement, therefore, these variations in type of traffic must be considered.

Variations in the rated capacities of motor trucks using highway routes are an excellent basis for determining the type of motor-truck traffic. Small-capacity trucks are designed to carry light loads and although overloading (loading beyond the rated capacity of the truck) is not uncommon, it can not be practiced beyond a certain degree. The rated capacity of a truck is found to bear a close relation to the average load transported by it; and the capacities of all trucks using a highway will bear a similar relation to the tonnage transported over the highway. The proportion of light, medium, and heavy trucks passing over the highways of a State is the primary factor in the determination of types of motor-truck traffic.

Additional evidence concerning motor-truck traffic is obtained by an analysis of net and gross loads and of rear-axle and wheel loads. This evidence is not only valuable in the selection of highway design and type of pavement but also in traffic control and the regulation of overloading.

THE HALF-TON TRUCK PREDOMINATES

One-half ton is the predominant capacity of motor trucks using the Connecticut highways, approximately one-fourth of all trucks recorded during the survey being of that size. Most important, however, from the standpoint of the weight and number of the vehicles, is the 5-ton capacity, which was represented in the traffic by one-tenth of the total number of trucks. Table 1 shows relatively the number of motor trucks of all capacities observed in the State as a whole during the survey period. The trucks of 1-ton capacity and under represent on the highways a much smaller percentage of the total traffic than they do of the total registration, while all other capacity groups are present in greater proportion in the traffic than in the registration lists. It is apparent, however, from Table 1 that, in the State as a whole, the motor-truck movement consists very largely of small-capacity trucks, although the heavy-truck movement is much heavier than the registration of such trucks would indicate.

[2] Status of the Motor Truck Impact Tests of the Bureau of Public Roads, by C. A. Hogentogler, PUBLIC ROADS, vol. 5, No. 9, p. 14.

TABLE 1.—*Distribution of observed motor trucks by capacity* [1]

Capacity of trucks	Percentage of total number of observed trucks	Capacity of trucks	Percentage of total number of observed trucks	Capacity of trucks	Percentage of total number of observed trucks
Tons	*Per cent*	*Tons*	*Per cent*	*Tons*	*Per cent*
½	25.1	2	9.7	5	10.2
¾	3.8	2½	3.7	5½	.4
1	18.4	3	1.7	6	.3
1¼	12.5	3½	6.7	6½	.6
1½	6.0	4	.7	7½	.2

[1] Based on 82,738 trucks.

It is possible from a study of the capacity of trucks using the highways of the State to classify certain routes, for purposes of highway design and surface type selection, as terminal highways and others as class A, B, and C highways. A terminal highway may be defined as a highway connecting large industrial centers, not widely separated between which there is a daily motor-truck traffic which consists of a large number of trucks of all capacities but especially of large-capacity trucks. Class A highways may be defined as carrying a smaller number of motor trucks of all capacities than terminal highways; class B highways as those the traffic of which consists mainly of small-capacity trucks; and class C highways as those over which the traffic of motor trucks of all capacities is relatively unimportant. In addition to the classification of highways, it is possible from a study of the movement of trucks of various capacities to establish certain general principles regarding the movement.

Figures 4 and 5 illustrate the movement of small and large-capacity trucks over the Connecticut highway system. Several significant features are observable in the movement illustrated by these figures. One of these is the great volume of ½ to 2½-ton trucks (fig. 4) observed around large centers of population and between adjacent large centers of population. This condition is apparent around Hartford, New Haven, and Bridgeport and is accounted for, in large part, by the fact that large cities and towns are distribution centers for commodities and because, in this distribution of commodities, the small-capacity truck is in general the most economical unit. The movement of small-capacity trucks is predominantly a local or short-haul movement. This is particularly true of the ½ to 1½-ton trucks, the average trip mileage of which ranges from 12 to 18 miles. Table 2 shows the average trip mileage of motor trucks of various capacities.

TABLE 2.—*Average trip mileage of motor trucks of various capacities*

Capacity	Average trip	Capacity	Average trip
	Miles		*Miles*
½ ton	12	4 tons	30
¾ ton	17	5 tons	45
1 ton	15	5½ tons	54
1¼ tons	18	6 tons	36
1½ tons	17	6½ tons	42
2 tons	27	7½ tons	60
2½ tons	34		
3 tons	29	All capacities	22
3½ tons	33		

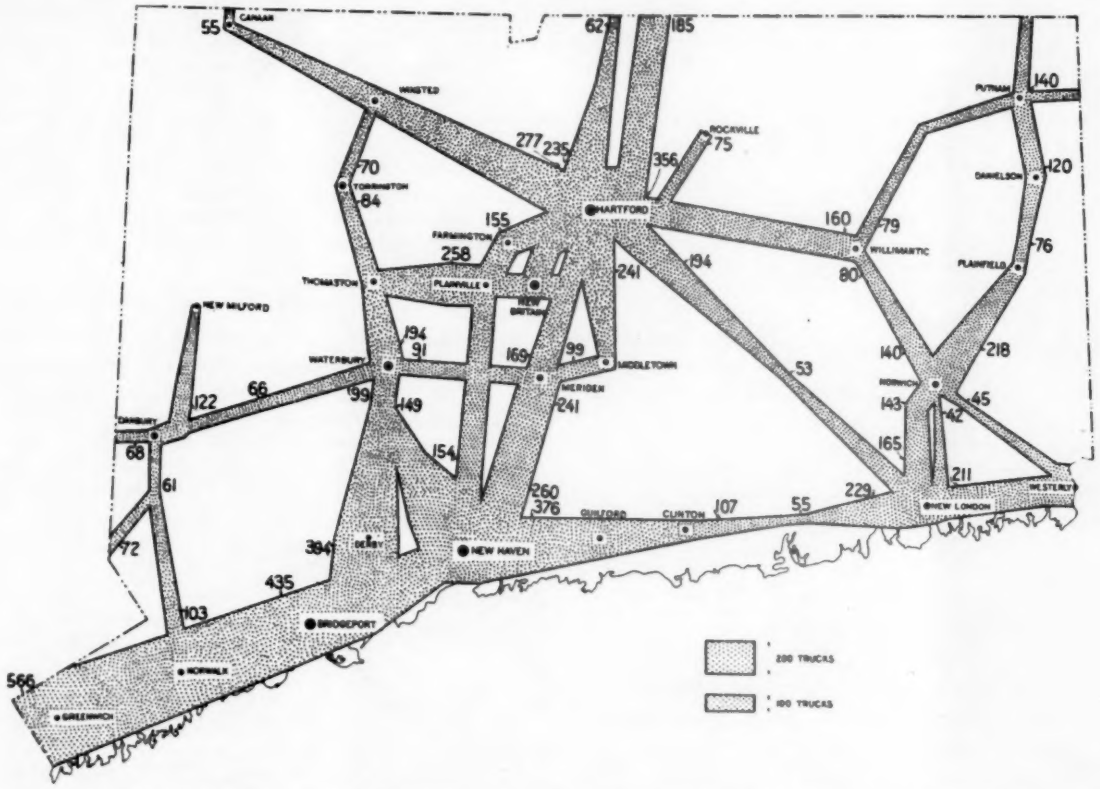


FIG. 4.—AVERAGE DAILY TRAFFIC OF SMALL-CAPACITY TRUCKS (ONE-HALF TO 2½ TONS) ON THE IMPORTANT HIGHWAYS OF CONNECTICUT

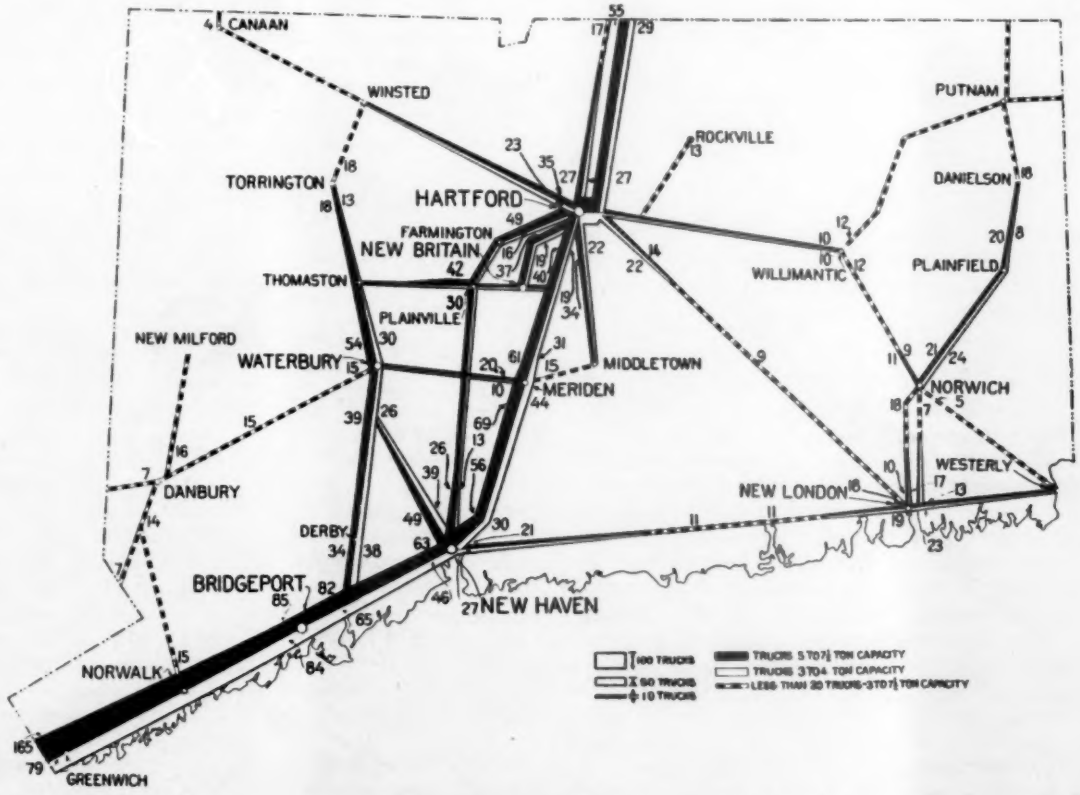


FIG. 5.—AVERAGE DAILY TRAFFIC OF LARGE-CAPACITY MOTOR-TRUCKS (3 TO 7½ TONS) ON THE IMPORTANT HIGHWAYS OF CONNECTICUT

The location of the State is a contributory factor to the long-haul movement of large-capacity trucks. Connecticut is a highly developed industrial area and its highways are the main traffic arteries between New York City and New England points, resulting in a large proportion of long-distance haulage by large-capacity vehicles.

TRUCK OVERLOADING PRACTICES

Approximately two-thirds of all motor trucks observed on the Connecticut highways during the course of the survey were loaded.

Comparing the large and small-capacity trucks, it was found that a somewhat larger proportion of the former were loaded. Of the total number of ½-ton trucks, for instance, 60.5 per cent were found to be loaded; while the loaded 5-ton trucks were 66.3 per cent of the total number. Although the differences between the proportion of loaded small-capacity and large-capacity trucks are not very great, it is apparent that the large-capacity trucks more frequently get return loads.

The general tendencies in motor-truck loading are shown by the average net and gross weights for trucks of each capacity as recorded in Table 3.

There is a tendency to load the 2, 2½, 3½, 5, and 6-ton trucks nearer the limit of their rated capacities. Trucks of these capacities can therefore be expected to be the principal motor trucks carrying loads in excess of rated capacity, since the ratio of their average net load to their capacity is higher than in the case of the other capacities.

TABLE 3.—*Average net and gross weight of trucks of the several capacities*

Capacity	Number of trucks	Average net weight	Average gross weight
		Pounds	*Pounds*
½ ton	5,072	720	2,950
¾ ton	1,375	1,090	5,210
1 ton	5,167	1,440	4,370
1¼ tons	3,443	1,560	5,270
1½ tons	1,679	2,310	7,350
2 tons	4,435	3,570	10,040
2½ tons	1,859	4,660	11,580
3 tons	335	4,430	12,770
3½ tons	3,507	6,020	15,820
4 tons	148	6,690	16,820
5 tons	6,897	8,680	20,170
5½ tons	236	8,440	20,380
6 tons	16	10,900	22,200
6½ tons	430	10,180	22,590
7½ tons	218	9,520	22,200

Almost one-third of the loaded motor trucks observed on the Connecticut highways during the survey carried net loads in excess of their rated capacities. Of the total number of loaded trucks, 30.2 per cent were loaded over their rated capacity and 2.1 per cent had gross weights in excess of 25,000 pounds. Of all sizes of trucks, those of 2, 2½, 3½, and 5-ton capacity were found most frequently to be loaded beyond their rated capacity. The percentages of trucks of these sizes so overloaded were 38.1, 41.8, 38.1, and 41.1 per cent, respectively.

The fact that 2.1 per cent of the total gross loads exceed the 25,000-pound legal limit is significant. No gross loads over 25,000 pounds were found on trucks of 3-ton capacity or smaller. It would be almost impossible for trucks of these smaller sizes to carry a 25,000-pound gross load. For this reason it would probably be more accurate to compute the percentage of loads in excess of the gross-weight limit on the basis of the number of loaded 3½ to 7½-ton trucks. Applying this method it is found that of the total number of 3½ to 7½-ton loaded trucks recorded, 6.4 per cent were loaded in excess of 25,000 pounds gross. On the terminal and class A highways overloaded trucks are more frequent. The highest percentage of trucks loaded beyond their rated capacity was found on the Boston Post Road.

TYPE OF TIRE EQUIPMENT

Pneumatic tires are used on 99 per cent of the ½-ton trucks. They also form the chief tire equipment for the ¾, 1, 1¼, and 1½-ton trucks. The trucks of larger capacity are mainly equipped with solid tires on both front and rear wheels, although there is some usage of combinations of the two tire types, using the solid type on the rear wheels and the pneumatic type on the front wheels.

The average net and gross loads of trucks vary considerably for trucks of the same capacity according to the type of tire equipment. Trucks equipped with pneumatic tires on both front and rear wheels are, in general, less heavily loaded than those which are equipped either with solid tires only or with a combination of pneumatic and solid tires. The heaviest loading occurs on the trucks that have solid tires on all four wheels.

Analyzing the trip mileage of the trucks with respect to the tire equipment, it appears that the majority of pneumatic-tired trucks—84.5 per cent—travel less than 40 miles. Of the solid-tired trucks, 58.8 per cent travel less than 40 miles; and of all trucks with the three types of tire equipment, 3.5 per cent of the pneumatic tired, 12.9 per cent of the solid tired, and 24 per cent of those equipped with a combination of solid and pneumatic tires, travel 100 miles or more at a trip.

LOADS PER INCH WIDTH OF TIRE

In order to determine the extent of violation of the statute prohibiting loads in excess of 800 pounds per inch width of solid tire and also providing that no commercial vehicle shall be so loaded that the weight on one axle is less than 20 per cent of the gross weight, an analysis was made of the weights of 4,580 loaded trucks. Excess loads per inch of width for the front axle were found to be exceptional. Of the 4,580 trucks analyzed, 102, or 2.2 per cent, were found to have loads in excess of 800 pounds per inch width of tire on the rear axle.

Examining the extent to which the overloading indicated by violation of this statute is confirmed by the other determinants of overloading—that is, loading in excess of rated capacity and loading in excess of 25,000 pounds gross weight—it is found that of the 4,580 trucks referred to above 2,810, or 61.4 per cent, were loaded to less than their rated capacity and of these only 20, or 0.7 per cent, were loaded in excess of 800 pounds per inch width of tire, channel measurement. Of the 1,770 trucks, 38.6 per cent of the total number, that were loaded in excess of rated capacity, 82, or 4.6 per cent, were loaded in excess of 800 pounds per inch width of tire, channel measurement; and of the 144 trucks the gross weight of which exceeded 25,000 pounds, 27, or 18.8 per cent, violated the tire-weight statute.

Data are also recorded and analyzed in the report as to the results secured by determining the width of tires by inside channel measurements and actual road contact measurements. The results indicate that a limitation of 800 pounds per inch of tire, channel measurement, is approximately equivalent to a limitation of 1,000 pounds per inch of width measured at the point of contact with the road surface.

Measurements were also taken of the thickness of solid truck tires. Very few trucks were encountered with tires less than 1 inch in thickness and the number operating on tires less than 1.5 inches in thickness varied from 2.8 per cent of the loads in excess of 25,000 pounds gross weight to 8.5 per cent of the trucks with less-than-rated-capacity loads. Over 60 per cent of all trucks operate on tires between 1.5 and 2.4 inches in thickness.

HIGHWAY UTILIZATION

The daily vehicle utilization of Connecticut highways is indicated by Figures 2 and 3. Net tonnage transported is the most reliable basis for the measurement of the service value of a highway for the transportation of commodities.

The 1,114 miles of improved highways in the State trunk-line system carry an average of 159,000 net ton-miles and 575,000 gross ton-miles of motor-truck traffic per day. During the year period—September, 1922, to September, 1923—these highways carried approximately 58,000,000 net ton-miles and approximately 210,000,000 gross ton-miles of truck traffic. During the same period the total vehicle utilization of the State system was approximately 414,000,000 vehicle-miles, of which 59,700,000 were truck-miles and 354,300,000 were passenger car- miles. The State trunk highway system includes 7.2 per cent of the total highway mileage in the State. The State-aid system includes 4.3 per cent and the town roads 88.5 per cent of the total mileage of the State. No accurate data regarding the vehicle-mileage utilization of the State-aid and town highway systems are available; but on the basis of scattered data it is estimated that approximately 60 per cent of the total vehicle mileage is on the State highway system, and that the total annual vehicle-mileage utilization of all highways in Connecticut is therefore approximately 690,000,000 vehicle-miles.

TABLE 4.—*Trip mileage of passenger cars used for business and nonbusiness purposes*

Trip mileage	All passenger cars	Business cars	Nonbusiness cars
	Per cent	*Per cent*	*Per cent*
0–19	55.7	65.3	48.0
20–39	16.3	14.4	17.9
40–59	9.2	8.2	10.1
60–79	5.0	3.9	5.9
80–99	3.6	1.7	5.1
100–149	4.3	3.3	5.1
150–199	1.7	1.2	2.1
200–299	2.7	1.5	3.7
300–399	.5	.2	.7
400–499	.2	.1	.4
500 and over	.8	.2	1.0
Total	100.0	100.0	100.0

Of the annual 354,300,000 passenger car-miles on the State system, 32.3 per cent, or approximately 114,400,000 passenger car-miles, represents the business use of passenger cars, and 67.7 per cent, or approximately 239,900,000 passenger car-miles, represents the nonbusiness use of passenger cars. The average trip mileage of passenger cars used for business purposes is considerably below the corresponding average for nonbusiness usage, as indicated by the analysis of the two kinds of usage presented in Table 4.

Of all passenger cars using the highways 44.5 per cent are business cars and 55.5 per cent nonbusiness cars. The variation between the proportion of business and nonbusiness usage on a vehicle basis and on a mileage basis is due to the shorter average trip mileage of business cars.

The percentages of all cars used for business and nonbusiness purposes, classified according to trip mileage, are shown in Table 5.

The number of passengers per car averages 2.7 persons for all passenger cars. For business cars the average is 1.8 persons, and for nonbusiness cars, 3.2 persons. The passenger mileage on the State highway system for the year period was 206,000,000 for business cars and 768,000,000 for nonbusiness cars, or a total of 974,000,000 passenger-miles.

TABLE 5.—*Percentages of all passenger cars used for business and nonbusiness purposes, classified according to trip mileage*

Trip mileage	Business cars	Nonbusiness cars
	Per cent	*Per cent*
0–19	52.2	47.8
20–39	39.3	60.7
40–59	39.4	60.6
60–79	34.8	65.2
80–99	21.6	78.4
100–149	34.5	65.5
150–199	30.9	69.1
200–299	24.6	75.4
300–399	17.6	82.4
400–499	17.2	82.8
500 and over	12.6	87.4
Total	44.5	55.5

STATE SYSTEM EARNS BIG RETURN ON INVESTMENT

Applying assumed values for saving in vehicle operation of 1 cent per passenger car-mile and 3 cents per truck-mile to the traffic on the 1,114 miles of the State trunk highway system, an estimated service value of the highway system can be obtained. As stated before the annual vehicle mileage on this system during the year period—September, 1922, to September, 1923—was approximately 414,000,000 vehicle-miles, of which 59,700,000 were truck-miles and 354,300,000 were passenger car-miles. On this basis of valuation the annual service value of the system is $1,791,000 for truck traffic and $3,543,000 for passenger car traffic, a total of $5,334,000 for the system.

A valuation based on motor-vehicle operating costs, however, does not represent the total service value produced by the highway system and the vehicles using the highways. Highway improvements increase real property values. Highway transportation adds time utility to the value of goods by the rapid movement at the time of demand and also produces place utility by making goods available for use by transporting them from the place of supply to the place of demand.

The value in 1923 of the 1,114 miles of improved highways on the State trunk-line system, including bridges but exclusive of right of way, is estimated by the Connecticut State Highway Commis-

sion at approximately $23,000,000. Based on the above estimate of the service value of the highway system to highway users, and without considering the additional service value indicated above, the State trunk highway system earns an annual return of approximately 23 per cent on the investment.

Vehicles of foreign registration form an important part of both motor-truck and passenger-car traffic on the State system. Foreign trucks comprised 10.9 per cent of all trucks recorded, but on account of their greater trip mileage (40 miles over Connecticut roads as compared with 14 miles for Connecticut trucks) the utilization on a ton-mileage basis is much higher. They also carry a greater tonnage than the Connecticut trucks. This is to be expected, since most of them are operating on the longer hauls where the larger capacities are generally used. On the basis of ton-mileage the foreign trucks furnish almost one-third of the total truck traffic.

Passenger cars of foreign registration were 21.1 per cent of all passenger cars recorded and furnished 43.4 per cent of the total passenger-car mileage.

TRANSPORTATION OF COMMODITIES

In 1923 there were 29,140 and in 1924 33,776 motor trucks registered in Connecticut. These motor trucks were in constant use carrying commodities over the highways and streets. During the period—September, 1922, to September, 1923—the haulage of these commodities over the 1,114 miles of the State highway system amounted to approximately 58,000,000 ton-miles and the inclusion of other highways and city streets would substantially increase this amount.

Motor-truck transportation in the State is of three principal types.

1. Transportation within the market and trading area of a city or town, including—
(*a*) Distribution of commodities from wholesaler to retailer, and from retailer to consumer.
(*b*) Marketing of commodities produced in the area, and
(*c*) Pick-up and delivery service between railroad or water terminals and shipper and consignee.

The movement is purely local, the major part of it being within the city or town. It uses the rural highways only in so far as the market or trade area of the city extends beyond its political limits.

2. Complete transportation from the shipper's place of business to the consignee's place of business for comparatively short-haul shipments. This type of transportation is inter-urban rather than local or suburban in character and is generally limited to distances of less than 40 miles.

3. Comparatively long-distance transportation, including—
(*a*) The transportation of specialized commodities, notably those which require a special preparation for shipment by rail or water that can be avoided by motor-truck shipment; and those which, because of their high value or their perishability, require rapid-delivery service; and
(*b*) Emergency transportation during periods of congestion and embargoes on other transportation facilities.

From Table 6 it is evident that of the total net tonnage transported over the State highway system more than one-third is moved distances of less than 10 miles, approximately two-thirds is moved distances of less than 30 miles, and only 15.2 per cent is moved distances of 60 miles and over. The table includes commodities transported over the State system only and excludes the large volume of motor-truck tonnage which is transported over city streets.

TABLE 6.—*Distribution of net tonnage of commodities transported by motor truck over the Connecticut State highway system by length of haul*

Length of haul (miles)	Proportion of total net tonnage	Length of haul (miles)	Proportion of total net tonnage
	Per cent		*Per cent*
0–9	36.3	70–79	2.6
10–19	19.2	80–89	.8
20–29	11.6	90–99	1.0
30–39	9.1	100 and over	8.6
40–49	4.0		
50–59	4.6	Total	100.0
60–69	2.2		

Approximately 350 distinct commodities were recorded on trucks using the State highway system during the period of observation, but of the total net tonnage 69 per cent was made up of manufactured goods. The distribution by types of commodities is shown in Table 7.

TABLE 7.—*Principal commodities transported by motor truck on State highway system*

Commodity	Percentage of total net tonnage	Commodity	Percentage of total net tonnage
Groceries	6.8	Ice cream	2.0
Gravel, sand, and crushed rock	5.3	Iron and steel bar	1.8
General express	4.8	Brick	1.5
Gasoline	4.5	Feed and grain	1.5
Household goods (used)	4.5	Furniture (new)	1.4
Coal	3.3	Vegetables	1.3
Lumber	3.3	Paper	1.2
Bread and bakery goods	3.0	Wire	1.1
Meat, fresh	2.9	Ice	1.0
Milk, fresh	2.7	Tires, rubber	1.0
Fruits	2.7	Wood, cord, and kindling	.9
Brass, copper, and lead	2.5	Miscellaneous commodities	34.4
Beverages	2.4		
Textiles	2.2	Total	100.0

The length of haul and the average unit load of the different commodities varies considerably. Of the materials hauled 9 miles and less, gravel, sand, and stone are first in importance; in the 10 to 19 mile haul they rank third in importance, and for longer hauls they are not among the important commodities. Coal appears as an important commodity only in the shortest haul groups, groceries in all haul groups up to 70 miles, and gasoline among the commodities hauled all distances up to 30 miles. The commodities of greatest importance in the long-haul groups are household goods (used), textiles, rubber tires, and crude rubber. Household goods increase in relative importance with increase in the distance hauled, constituting 5.1 per cent of the movement from 40 to 49 miles and 23.5 per cent of the haulage for distances of 100 miles and more. Rubber tires and crude rubber appear among the important commodities only for hauls of 100 miles or more, indicating the very specialized character of the movement over such long distances.

The movement of foodstuffs, consisting largely of retail distribution and the marketing of such products as milk, is predominantly a small-truck movement. Household goods are transported chiefly in trucks of 1½ to 4 tons capacity, and constitute 11.7 per cent of all goods transported in 2½-ton trucks. Gasoline is hauled largely in trucks of from 2 to 4 tons capacity,

and gravel, sand, stone, brick, and cement are hauled largely in trucks of 3½-ton and larger capacities. Textiles, metal products, and paper (largely news print) are also hauled in large-capacity trucks.

TRUCK AND RAIL TONNAGE COMPARED

Considerable data were collected as to the character and volume of freight transported by highway and railroad between selected points both within and outside of the State. The points selected represent distances varying from 17 to 140 miles, and all have direct connection by rail and highway. Between New Haven and Bridgeport 75.2 per cent of all the freight moves by motor truck, 0.9 per cent as l. c. l. rail shipment, and 23.9 as car-load rail shipment. The distance is 17 miles by rail and 18 miles by highway. Between New York City and Waterbury, a distance of 93 miles by highway and 88 miles by rail, the figures are 8.7 per cent by motor truck, 17.5 per cent l. c. l. freight, and 73.8 per cent car-load freight.

As motor-truck freight is primarily a package, or small unit shipment, it is more strictly comparable with rail l. c. l. freight than with all rail freight. Of all package freight the motor truck carries over 90 per cent between points less than 60 miles apart. Between points over 60 miles apart the percentage varies considerably, but the tendency toward relatively decreasing truck tonnage with the increase in distance is very apparent.

The importance of the motor truck in the transportation of products of agriculture and products of animals is even more apparent. These classifications include a large part of the movement of perishable foodstuffs. For products of animals the motor-truck tonnage greatly exceeds the rail l. c. l. tonnage between all points analyzed except New York City and Springfield, a distance of approximately 134 miles, and exceeds the total rail tonnage between all points except New York City and Springfield, and New York City and New Haven. The large car-lot movement of these products between New York City and New Haven is largely accounted for by the fact that New Haven is the wholesale distribution market for a considerable area.

Of manufactures the motor-truck tonnage exceeds the rail l. c. l. tonnage between all points analyzed except New York City and Springfield, and New York City and Waterbury; but the total rail tonnage exceeds that of the motor truck for all distances over 60 miles and also between Hartford and Springfield, a distance of approximately 25 miles. Between the latter points, however, 3,312 tons of the total of 3,627.8 tons, or over 90 per cent of the carload tonnage of manufactures, consists of refined petroleum and its products.

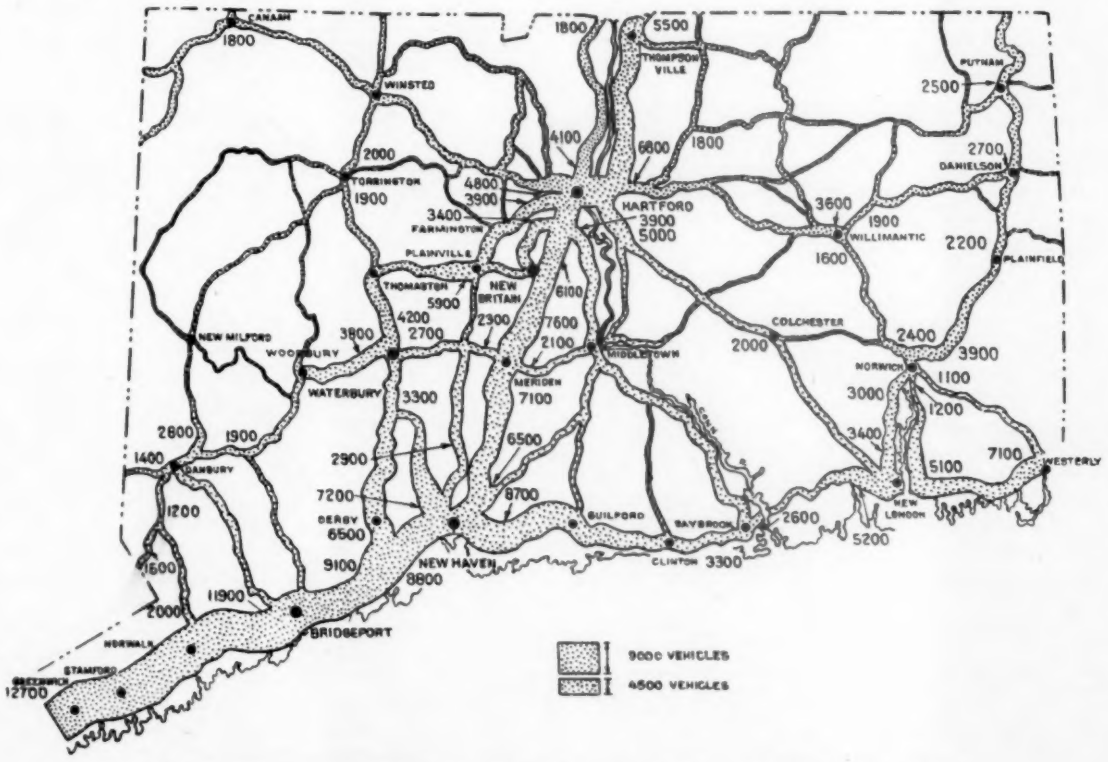


FIG. 6.—ESTIMATED TOTAL TRAFFIC DENSITY ON STATE HIGHWAYS IN 1930

The importance of the motor truck in the transportation of commodities is clearly indicated, and the data warrant the following conclusions:

1. A very considerable part of the package freight between origins and destinations in the Connecticut territory less than 50 miles apart is transported by motor truck.
2. As distance between origin and destination increases transportation by motor truck becomes of less importance.
3. The ratio of motor-truck freight to rail freight between two points varies greatly with distribution and marketing practices. Cities which are distributing points for surrounding areas receive a larger amount of freight in bulk lots, such as rail carload shipments, than cities which distribute to the local market alone.
4. For origins and destinations between which the exchange of freight includes bulk commodities, such as coal and oil, the

tonnage transported by motor truck compared with total rail tonnage is relatively small. As such commodities are a necessary part of the freight into nearly all cities, motor-truck freight becomes a relatively small part of total freight.

FORECAST OF TRAFFIC IN 1930

A knowledge of the trend of traffic development on a highway system is a prerequisite to the establishment of an adequate and scientific plan of highway improvement. The building of a highway which will not meet traffic demands during the expected life of the improvement is a poor investment, resulting in traffic congestion and early reconstruction. On the other hand, the building of a highway with a traffic capacity in excess of the need that may be expected to develop during the life of the improvement is also uneconomic, since it involves an outlay of funds which could more advantageously be used for other highway improvements. A knowledge of future traffic is therefore essential to the establishment of a sound plan of highway improvement.

The most scientific method of future traffic prediction is by projecting past traffic trends. This method has been found accurate in the prediction of population, business conditions, railway traffic, and other economic factors. Accurate prediction on the basis of past trends is possible only when the trend over a considerable period of years is known and also when the period is one of normal development.

While there are no adequate records of traffic development in the State, there are complete records of the motor-vehicle registration for a series of years, and the experience of other States demonstrates that these may be employed as a basis for traffic prediction, since it is found that there is a close and practically constant relation between the rates of growth of registration and traffic. The States in which the relation between the two factors has been determined are Maryland, Maine, and Wisconsin. In each of these States both traffic and registration records are available for a number of years.

An analysis of the data from these States indicates clearly that traffic and registration may be expected to increase at approximately equal rates and that the prediction as to registration may be taken as the basis for the prediction of traffic.

It may not be assumed, of course, that the future traffic will be distributed in exactly the same proportions as the present traffic on the various roads. The development of new highways, unusual industrial or resort developments, and suburban expansion will affect the traffic in smaller areas.

The number of persons per vehicle in Connecticut for each year since 1917 is easily determined from available registration statistics and has been plotted graphically. To this curve there has been fitted a smooth curve using the method of least squares, and the latter has been extended to indicate the persons per vehicle in 1930. Table 8 shows the estimated persons per car determined in this manner, the population estimated by methods used by the Bureau of the Census and the resulting registration calculated from these two sets of figures for each year between 1925 and 1930.

TABLE 8.—*Estimate of persons per car, population and motor-vehicle registration in Connecticut, 1925 to 1930*

Year	Estimated persons per car	Estimated population	Estimated motor-vehicle registration
1925	6.22	1,531,250	[1] 246,000
1926	5.47	1,558,640	285,000
1927	4.80	1,586,030	330,000
1928	4.22	1,613,410	382,000
1929	3.70	1,640,800	443,000
1930	3.25	1,688,180	513,000

[1] The actual motor vehicle registration in 1925 was 250,647 vehicles, varying from the estimated registration by less than 2 per cent.

By comparing the registration of 1923 with the estimated 1930 registration, as above, a factor of increase is determined which when applied to the observed traffic of 1923, assuming traffic and registration to increase in the same proportion, indicates the probable 1930 traffic on the principal roads as shown in Figure 6.

Assuming no change in the present State highway system between 1923 and 1930, the traffic upon these highways is expected to be as shown. The predicted density on the present heavy-traffic routes indicates the pressing need for a comprehensive improvement program during this period.

The Post Road may be expected to carry a daily average of 12,700 vehicles at the New York line, and an average of approximately 9,000 vehicles per day on the section between Greenwich and New Haven; the same route from New Haven to the Massachusetts line may be expected to carry over 6,000 vehicles per day over the greater part of the route.

If the present ratio between average traffic and maximum traffic continues until 1930, approximately two and one-half times the predicted average traffic may be expected to attempt to use these routes on a Sunday during the month of maximum traffic.

The tremendous volume of traffic that may be expected in 1930 on the Post Road and other heavy-traffic routes will require extensive enlargements of the traffic capacity of these routes or the opening of alternate routes in order that adequate highway service may be provided.

Improvements on routes of secondary traffic importance will also be required, particularly routes at present improved with the lower types of surfaces, but the present heavy-traffic routes will continue to be the most important problem in the provision of adequate and economical service to the users of the Connecticut highway system.

ADAPTATION OF ATTERBERG PLASTICITY TESTS FOR SUBGRADE SOILS

Reported by A. M. WINTERMEYER, Bureau of Public Roads

A NUMBER of soil tests have been investigated recently by the Bureau of Public Roads in an effort to develop a simple test which would indicate the effect of moisture on the supporting value of the soil or at least that moisture content beyond which a soil has little, if any, definite supporting value. Among the methods investigated has been the Atterberg soil plasticity test, and the results obtained to date with this test have been so satisfactory that it has been decided to employ it regularly in conjunction with the other tests now being used by the bureau in the surveys which are being made to determine the influence of subgrades, subbases and drainage on the condition of pavements. A detailed description of the procedure used in these surveys will be given in forthcoming articles in PUBLIC ROADS.

In the absence of definite knowledge as to the specific properties of soils which influence their behavior as road subgrades it has been assumed that volumetric changes and supporting value are of prime importance

FIG. 1.—RUBBER STOPPER, BRASS DISH, SPATULA AND GLASS PLATE USED IN MAKING LOWER PLASTIC LIMIT AND LOWER LIQUID LIMIT TESTS

and the principal effort has been directed toward the development of suitable tests for determining these properties, an important consideration being the adaptability of the tests to field use. It is in this respect that the laboratory tests for bearing power, moisture equivalent, and volumetric change have been unsatisfactory. They are not lacking in consistency of result or possibility of interpretation; but they require the use of equipment and instruments which can not be employed under field conditions, and the relatively long time necessary for their performance also militates against their use.

It is these facts which give importance to the field methods for determining moisture equivalent and lineal shrinkage [1] recently developed by the Bureau of Public Roads and lend interest to the plasticity test described by Albert Atterberg in the International Reports on Pedology, 1911.

Although plasticity has been defined by many authors, and is attributed by each to various factors, no authoritative definition has yet been given. We may say that a soil is slightly or highly plastic but such a characterization is vague in that the degree of plasticity is not definitely stated. We know, however, that the plasticity of a soil varies with the quantity of water added, increasing with the percentage of water up to a certain point beyond which any further addition of water reduces the plasticity and the soil assumes a liquid form. Passing over the many factors which

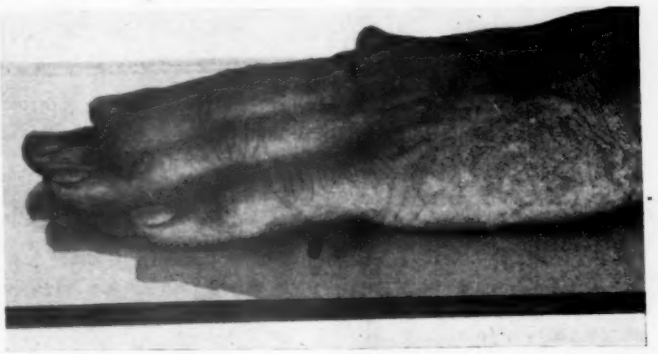


FIG. 2.—ROLLING PHASE OF THE LOWER PLASTIC LIMIT TEST

contribute to the plasticity of a soil, its application to subgrades concerns the two extreme points designated as the *lower plastic limit*, or that moisture content at which the soil becomes plastic, and the *lower liquid limit*, or that moisture content at which the soil passes from the plastic into the liquid state.

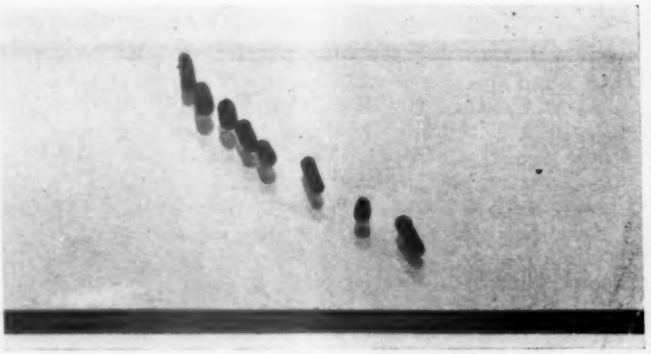


FIG. 3.—END POINT OR CRUMBLING PHASE OF LOWER PLASTIC LIMIT TEST

THE ATTERBERG PLASTICITY METHOD

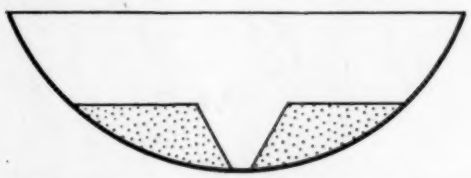
The apparatus required for the Atterberg tests, as made by the Bureau of Public Roads, includes a drying oven such as is usually found in all laboratories; a glass plate or some other smooth surface such as glazed paper upon which to roll the soil; a rubber stopper (preferably No. 12); a 3-inch spatula, and a brass dish about 3 inches in diameter and 1 inch in depth as shown in Figure 1. An evaporating dish may be used but there is always the danger of breakage and painful cuts resulting from its substitution.

To determine the lower plastic limit a sample of the soil, which has been passed through a 10-mesh or 2-millimeter sieve, is mixed with water until it becomes

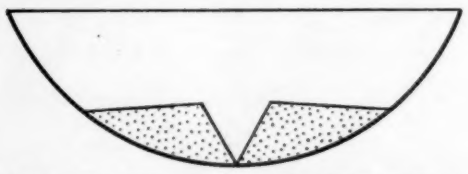
[1] Practical field tests for subgrade soils, by A. C. Rose, PUBLIC ROADS, vol. 5, No. 6, Aug. 1924.

plastic. It is then rolled with the palm of the hand on the glass plate or other smooth surface into threads or rolls about one-eighth inch in diameter as shown in Figure 2. The threads thus formed are then worked together and again rolled out as before; and this process is repeated until the soil crumbles instead of forming a thread, as illustrated by Figure 3. When this condition is reached the moisture content of the soil is determined and expressed as a percentage of the dry weight of the soil which is known as the lower plastic limit. The limiting condition is very easily recognized and no difficulty is experienced in closely checking the results.

In order to determine the lower liquid limit a small quantity of soil is placed in the brass dish and mixed



A.—SOIL SEPARATED BY A DISTANCE OF ABOUT ONE-EIGHTH INCH AT THE BOTTOM OF THE DISH BEFORE THE TEST



B.—BASE OF SOIL SECTIONS JOINED AT CONCLUSION OF TEST

FIG. 4.—CONDITION OF SOIL SAMPLE BEFORE AND AFTER DETERMINATION OF THE LOWER LIQUID LIMIT BY THE ATTERBERG METHOD

with water until it becomes pasty. It is then shaped into a smooth layer approximately three-eighths inch thick at the center, and divided into two portions with a spatula as indicated by Figure 4, *A*, so that the space separating the two portions at the bottom is about one-eighth inch. One side of the dish is then rapped sharply with a glancing blow 10 times against the rubber stopper held in one hand, after which the other side is similarly rapped the same number of times, care being taken to make the impacts as nearly as possible of the same intensity and not too vigorous. The object of this procedure is to cause the two portions of soil to join at the bottom, as shown in Figure 4, *B*, and when the moisture content is just sufficient to cause such a running together with the stipulated amount of rapping the lower liquid limit is said to have been reached. The appearance of the soil at the beginning and the end of the test is shown by Figures 5 and 6, respectively.

If after the prescribed amount of rapping the two portions of the soil do not run together and adhere more water is added and thoroughly incorporated by mixing; the divided pat is reformed and rapped as described; and this entire process is repeated, adding a little water each time, until the desired end is attained. The moisture content of the soil is then determined and expressed as a percentage of the dry weight of the soil which is the lower liquid limit.

To determine definitely whether the two portions are actually joined the spatula may be used to push

FIG. 5.—BASE OF SOIL AT BEGINNING OF LOWER LIQUID TEST SEPARATED BY A DISTANCE OF ONE-EIGHTH INCH

one away from the other. If they separate along the line of division the end has not been reached and the test must be repeated with more water. The water should be added a small quantity at a time in order to avoid passing the critical point. If there is reason to believe that too much water has been added dry soil instead of water may be added until the proper end point has been reached.

The operator will soon learn to recognize the approach of the lower liquid limit by the ease with which the spatula will cut through the pat. This observation will serve as a guide and a warning that the desired end has been nearly reached and that any further water required must be added in very small quantities, preferably only a drop at a time.

FIG. 6.—CONDITION OF SOIL AT THE LOWER LIQUID LIMIT. TWO PORTIONS OF SOIL RUN TOGETHER AND ADHERE AT BOTTOM

TESTS OF SANDY SOILS MOST DIFFICULT

The testing of sandy soils is more difficult and requires greater skill than the clay soils, and certain changes in the procedure described above are desirable. If the soil is friable or granular it is not advisable to strike the dish a glancing blow at the side. Instead it should be struck perpendicularly at the bottom. Soils of this class do not adhere firmly to the dish, and when struck at the side both portions will slip.

In conducting both tests certain precautions must be taken; otherwise close checks can not be expected. It is necessary that the soil and water be thoroughly mixed, especially in determining the lower liquid limit. It is extremely difficult to effect a uniform distribution of moisture in clay soils, and these must be worked until the consistency of the soil appears the same throughout. Here the sense of feeling must be the guide. The author has made several moisture determinations on different parts of a pat of heavy clay soil which appeared to be mixed thoroughly, yet showed a variation nearly as high as 2 per cent.

The compacting of the soil in the dish is another important factor. It is not possible to define exactly the pressure that should be exerted with the spatula when pressing and shaping the pat. It should be just great enough to form the soil into a compact mass, and this pressure should be approximately the same on all soils tested. The necessity for this is obvious. It can be readily seen that a soil differently compacted will require different moisture contents to reach the lower liquid limit and the results will therefore differ widely. Recognizing the end point seems to be the most difficult problem, but experience makes it possible for independent operators to check within very close limits.

In determining the lower liquid limit two methods may be used. Plastic soils may be worked from the plastic up to the liquid state or back to the lower liquid limit from the fluid state. Friable soils may be worked from the semi solid state to the lower liquid limit or back to the lower liquid limit from the fluid state. It is easier to work from the fluid state down to the lower liquid limit, but there is the disadvantage of handling and mixing greater quantities of soil, and as a rule the end point is passed and more water must be added to reach the end point.

THE MEANING OF THE PLASTIC RANGE

The difference between the lower plastic limit and the lower liquid limit, as determined by these tests, is what is called the *coefficient of plasticity* or *plastic range* of the soil, and the greater this range the more plastic is the soil. The difference between the two percentages expresses the range of moisture content within which the soil is in a plastic state.

Soils may be divided into two classes designated as plastic and friable, and the degree of plasticity or friability is indicated by the plastic range, the greater ranges indicating the more plastic soils. As we add water in increasing quantities to a plastic soil it passes from the solid or semisolid state into the plastic state and then into the liquid state. The friable soils, on the other hand, pass directly from the solid to the liquid state. The coefficient of plasticity or plastic range of plastic soils may vary from less than 2 in the more sandy or silty soils to as high as 35 or more in the heavier clays; while that of the friable soils is zero, i. e., they have no plastic range.

The silty friable soils differ from the sandy friable soils in that they require a greater percentage of moisture before they reach the point of transition to the liquid state. Quite frequently soils are encountered that appear sandy yet have a high plastic range.

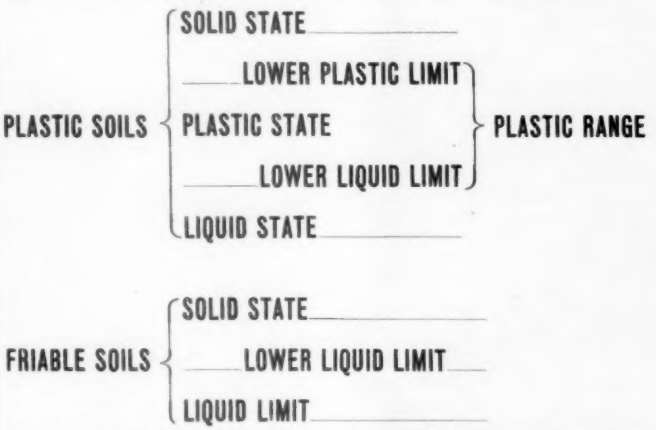


FIG. 7.—PLASTIC SOILS HAVE A PLASTIC RANGE EXTENDING FROM THE LOWER PLASTIC LIMIT TO THE LOWER LIQUID LIMIT. FRIABLE SOILS HAVE ONLY A LOWER LIQUID LIMIT

According to Kinnison [2] the shape of the sand particles has a much greater influence on the plasticity than the size, and this observation may explain such apparently anomalous cases. The different transition stages which distinguish the plastic from the friable soils are shown diagrammatically in Figure 7.

TABLE 1.—*Original and check results of the plasticity tests on plastic soils by an experienced operator*

State	Soil sample number	Lower plastic limit		Lower liquid limit	
		First test	Second test	First test	Second test
		Per cent	*Per cent*	*Per cent*	*Per cent*
Minnesota	1003	15.7	15.5	17.4	17.6
Maryland	1711	18.9	18.4	22.3	22.1
Ohio	1459	19.8	21.2	22.9	22.8
Virginia	1838	20.6	20.8	22.9	23.2
Do	1835	21.3	20.9	25.5	25.7
Do	1841	22.8	22.9	27.2	27.1
Do	1833	23.5	23.6	30.6	30.8
Do	1832	25.0	25.1	31.2	31.3
South Dakota	1284	26.3	26.1	45.2	45.3
Do	1282	26.6	27.7	49.0	49.0
Virginia	1987	27.5	27.8	40.4	40.8
Do	1837	29.1	29.0	34.0	33.8
Do	1650	30.2	29.5	44.5	44.8
South Dakota	1283	32.3	29.2	50.8	51.3
Texas	1696	32.5	32.1	55.2	53.3
North Carolina	1619	27.3	27.9	50.7	50.7
Texas	1699	33.3	33.4	68.0	67.8
Do	1686	35.6	33.4	58.0	58.0
South Dakota	1273	36.5	35.7	53.7	55.4
Texas	1698	36.2	36.1	68.6	67.8
South Dakota	1274	44.2	42.8	60.1	60.9
Do	1276	43.5	43.5	57.8	57.8

CONSISTENCY OF TEST RESULTS PROVED BY BUREAU EXPERIENCE

The experience of the bureau with the Atterberg tests indicates that an experienced operator making duplicate tests may be expected to check his results very closely. This is shown by the check results, representative of over 500 soils tested to date, given, for the plastic soils in Table 1, and, for the friable soils, in Table 2. The proximity of all points in Figures 8, *A* and *B*, further emphasizes the consistent agreement

[2] A study of the Atterberg Plasticity Method, by Chas. S. Kinnison, Bureau of Standards, Technologic Paper No. 46, May 25, 1915.

between duplicate tests. These curves illustrate the consistency of the tests in the hands of experienced operators.

In order to ascertain the maximum variation that may be expected two series of tests have been made on the same soils at different times and with different operators, one experienced and the other inexperienced.

TABLE 2.—*Original and check results of the plasticity tests on friable soils by an experienced operator*

State	Soil sample number	Lower liquid limit	
		First test	Second test
		Per cent	*Per cent*
South Carolina	1563	15.3	14.4
Virginia	1766	16.6	16.2
Do	1763	18.0	18.5
Do	1762	19.8	19.0
Do	1783	20.5	20.3
Do	1774	20.3	21.4
Do	1772	22.4	22.4
Do	1784	23.6	23.3
Do	1856	23.8	23.8
Do	1769	24.8	24.6
Do	1874	27.8	27.7
Do	1776	30.7	31.6
Minnesota	37	32.1	31.9
Virginia	1915	37.1	37.1
Do	1442	41.2	43.4
Do	1649	44.9	45.0

TABLE 3.—*Original and check results of the plasticity tests made by different operators and at different times*

State	Soil sample number	Lower plastic limit	
		First test	Second test
		Per cent	*Per cent*
Virginia	504	11.7	13.0
Do	499	12.2	13.6
Do	492		
Do	502	12.8	15.8
Do	500	12.1	12.4
Do	496	13.3	15.5
Do	489	12.7	14.2
Do	486	15.1	19.0
Colorado	1632	15.9	17.5
Virginia	507	17.5	16.8
Colorado	1630	14.2	14.0
Do	1631	14.3	21.3
Do	1626		
Do	1627	17.2	14.8
Do	1628	15.7	14.0
Do	1625	17.3	15.5
Illinois	1611	22.7	23.2
Colorado	1624	21.2	19.6
Ohio	1272	21.5	21.8
Colorado	1622	18.8	17.9
Utah	763	20.0	24.3
Colorado	1623		
Utah	758	23.9	26.2
Do	759	23.5	24.0
Nevada	760	26.3	25.5
South Dakota	1281	26.4	27.3
Nevada	761	28.0	30.2
Utah	756	25.1	27.5
Do	762	24.2	24.9
Do	757	24.7	25.0
South Dakota	1283	30.8	23.1
Do	1277	36.1	33.0
Louisiana	1477	25.3	21.4
South Dakota	1273	34.2	31.2
Minnesota	924	28.1	28.1
South Dakota	1274	43.5	44.2
Do	1276	43.5	41.7

Results of these check tests for a wide range of soils, from different States, are shown in Table 3 and by the curve in Figure 8, *C*. These data indicate the degree of accuracy which might be obtained in tests of the same soil types when carried on in different laboratories and by different operators. Although the agreement between the first and second tests might not be as close as some would expect, it is probable that the agreement is closer than would be expected from tests of other engineering materials (such as cement or concrete) carried on in a similar manner.

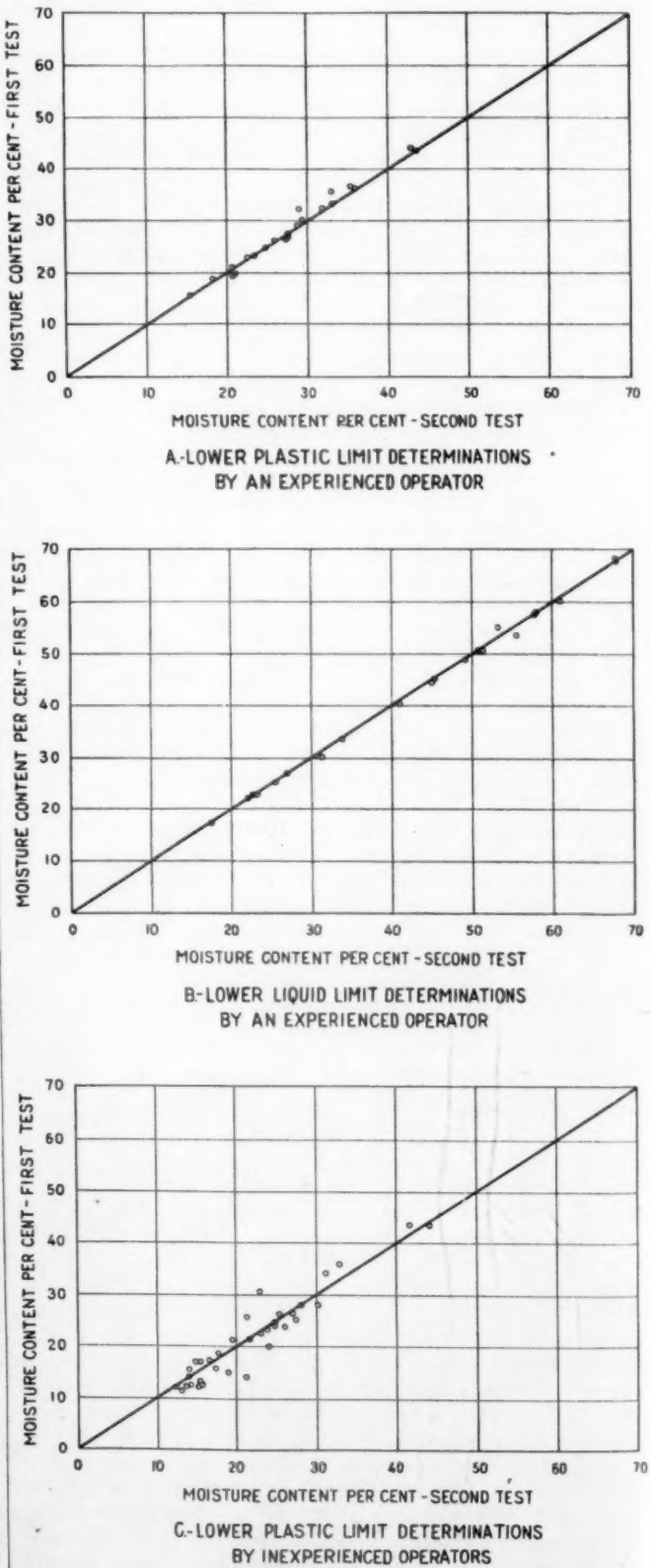


FIG. 8.—COMPARISON OF CHECK TESTS, USING THE ATTERBERG METHOD, BY THE BUREAU OF PUBLIC ROADS

FIFTH INTERNATIONAL ROAD CONGRESS OPENS AT MILAN, ITALY

UNITED STATES SENDS OFFICIAL DELEGATES

AT THE FIFTH International Road Congress, which opens at Milan, Italy, on September 6, the United States will be represented for the first time by official delegates. Acceptance of membership in the Permanent Association of International Road Congresses and authorization for the appropriation of expenses of delegates to the current meeting was provided by Congress during the closing days of the last session in Senate Joint Resolution 62, which was signed by the President on June 18.

Acting on the joint recommendation of the Secretaries of State, Agriculture, and Commerce, the President has appointed as official delegates to the Congress: Thomas H. MacDonald, chief United States Bureau of Public Roads; Paul D. Sargent, chief engineer State Highway Commission of Maine; John N. Mackall, chairman State Roads Commission of Maryland; H. H. Rice, vice president General Motors Corporation; Geo. Pyke Johnson, National Automobile Chamber of Commerce; H. C. MacLean, commercial attaché, Department of Commerce at Rome; and H. H. Kelly, assistant trade commissioner, Department of Commerce at Paris.

The delegation will sail from New York on the steamship *President Harding* leaving August 25 and will arrive at Milan in time to take part in all meetings of the Congress which will be opened on September 6 and continue at Milan for six days, closing in Rome on the following day, September 13.

Simultaneously with the congress an international road exhibition will be held, under the patronage of the Communal and Provincial Administrations and the Chamber of Commerce of Milan, in the Fiera Campionaria. The exhibition will open on the 1st and continue until the 20th of September.

PROGRAM OF THE CONGRESS

The following program of the congress has been announced in circulars just received in the United States:

MONDAY, SEPTEMBER 6.
Morning: 9 a. m.—Meeting of the International Permanent Commission (Castello Sforzesco). Opening of the offices for distribution of membership cards, etc. (Palace of Facolta Giuridica, Via S. Michele del Carso N. 25). 10.30 a. m.—Official sitting of the congress (Castello Sforzesco).
Afternoon: 2 p. m.—Sitting of the sections.
Evening: Receptions.

TUESDAY, SEPTEMBER 7.
Morning: 9 a. m.—Sitting of the sections.
Afternoon: 2 p. m.—Sitting of the sections.
4 p. m.—Visit to the exhibition and reception.

WEDNESDAY, SEPTEMBER 8.
Morning: 9 a. m.—Sitting of the sections.
Afternoon: 2 p. m.—Sitting of the sections.
4 p. m.—Visits.

THURSDAY, SEPTEMBER 9.
Visit to the Autodromo at Monza and the Autostrade. Milan Lakes.
Lunch at Varese at the invitation of Ing. Gr. Uff. Piero Puricelli.

FRIDAY, SEPTEMBER 10.
Morning: 11 a. m.—Sitting of the sections, with a view to arriving at conclusions.
Afternoon: Visits or receptions.

EXCURSIONS

SATURDAY, SEPTEMBER 11.
Group a.—To Lake Maggiore; return to Milan the same evening.
Group b.—To Lake Como; return to Milan the same evening.

SATURDAY AND SUNDAY, SEPTEMBER 11 AND 12.
Group c.—Milan, Tirano, Stelvio, Merano, Trento.
Group d.—Milan, Tirano, Aprica, Tonale, Trento.

MONDAY, SEPTEMBER 13.
3 p. m.: Official closing of the congress in Rome and official reception in the Campidoglio.

TUESDAY, SEPTEMBER 14.
9 a. m.: Archeological excursion.

SUBJECTS TO BE DISCUSSED

The program of subjects to be discussed by the congress, the names of the speakers for each subject, and the general speakers on each question are as follows:

FIRST SECTION

CONSTRUCTION AND UPKEEP

FIRST QUESTION, CONCRETE ROADS

Belgium.—(In collaboration): Messrs. E. Piens, chief engineer of bridges and roads, 33 Square Gutenberg, Brussels; Luyssen, engineer of bridges and roads, 33 Square Gutenberg, Brussels.

Denmark.—M. S. Ellert, chief engineer of bridges and roads of the county of Holback, Holback.

United States.—(In collaboration): Messrs. Clifford Older, M. Am. Soc. C. E., consulting engineer, 1739 Marquette Building, Chicago, Ill.; J. Shirley Bright, M. Am. Soc. C. E., construction engineer, U. S. Bureau of Public Roads, San Francisco, Calif.; Raymond W. Coburn, construction engineer, State Highway Department, Boston, Mass.; Charles R. Ege, Assoc. M. Am. Soc. C. E., manager highways bureau, Portland Cement Association, Chicago, Ill.; Herbert J. Kuelling, Assoc. M. Am. Soc. C. E., construction engineer, State Highway Department, Madison, Wis.; Robert M. Morton, Assoc. M. Am. Soc. C. E., State highway engineer, Sacramento, Calif.; Frank T. Sheets, M. Am. Soc. C. E., chief highway engineer, State Department of Public Works and Buildings Division of Highways, Springfield, Ill.; Leroy C. Smith, Assoc. M. Am. Soc. C. E., chief engineer, Wayne County Highway Commission, Detroit, Mich.; Charles M. Upham, Assoc. M. Am. Soc. C. E., formerly chief engineer, State Highway Department, Raleigh, N. C.

France.—Monsieur Féret, chief of the bridges and roads laboratory, Boulogne-sur-Mer.

Great Britain.—(In collaboration): A Harrison, esq., M. Inst. C. E., borough engineer and surveyor, Southwark, London S. E.; J. B. L. Meek, Esq., M. Inst. C. E., city engineer, Manchester; Richmond, esq., C. M. G., A. M., Inst. C. E., divisional road engineer, Ministry of Transport, London; W. P. Robinson, esq., county surveyor, Surrey County Council.

Italy.—M. Franklin Colamonico, inspecteur supérieur du génie civil, Ministry of Public Works, Rome.

Sweden.—Mr. Paul E. Wretlind, engineer of roads and bridges, director of the Limited Company "Wagförbättringer," Blasieholmsgatan, 3, Stockholm.

Low countries.—Dr. L. R. Wentholt, chief engineer of the Rijkswaterstaat (bridges and roads), Mariënburg, No. 80, Nimégue.

SECOND QUESTION, ROADS USING BITUMEN AND ASPHALT

Belgium.—Mr. Van Moere, chief engineer of roads and bridges, 1, rue Blondeau, Namur.

United States.—(In collaboration): Messrs. Charles S. Pope, M. Am. Soc. C. E., chief construction engineer, State highway department, Sacramento, Calif.; R. Keith Compton, M. Am. Soc. C. E., director of public works, Richmond, Va.; W. Herbert

Fulweiler, M. Am. Soc. T. M., chemical engineer, United Gas Improvement Co., Philadelphia, Pa.; Christian P. Jensen, M. Am. Soc. C. E., county surveyor, Fresno, Calif.; William H. Kershaw, Assoc. M. Am. Soc. C. E., manager the asphalt department, the Texas Co., Whitehall Building, New York City; Ralph E. Myers, M. Am. Soc. T. M., chemist New York State Highway Department, Albany, N. Y.; Philip P. Sharples, M. Am. Soc. T. M., consulting highway engineer, Redondo Beach, Calif.; Henry G. Shirley, M. Am. Soc. C. E., chairman State Highway Commission, Richmond, Va.; Francis P. Smith, M. Am. Soc. C. E., consulting highway engineer, 130 East Twenty-third Street, New York City

France.—(In collaboration): Messrs. Chauve, chief engineer of roads and bridges, Nice; Félix, engineer of roads and bridges, Versailles.

Great Britain.—W. J. Hadfield, esq., M. Inst. C. E., city surveyor, Sheffield.

Italy.—(In collaboration): Messrs. Giuseppe Sdralevich, chief engineer of the Technical Bureau of the Province of Milan; Ugo Conte, Technical Bureau of the Rome Municipality.

Sweden.—Mr. M. K. Joseph Gednt, engineer of roads and bridges, chief engineer of the "Nya Asfaltakiebolaget," Rörstrandsgatan, 3, Stockholm.

Low Countries.—Mr. M. B. J. Kerkof, member of the board of undertakings for the construction of modern routes, Blithoven (near Utrecht).

Switzerland.—(In collaboration): Messrs. R. Schlaepfer, cantonal engineer, Herisau; Dr. P. Schlaepfer, professor at the Federal Polytechnic School, Zurich.

Third Question. Standardization of Trials for Acceptance of Materials for Roads

Denmark.—Mr. M. H. Rygner, chief engineer of the town of Odense, Odense.

United States.—(In collaboration): Messrs. Albert T. Goldbeck, Assoc. M. Am. Soc. C. E., formerly chief division of tests, U. S. Bureau of Public Roads, Washington, D. C.; Duff A. Abrams, M. Am. Soc. C. E., engineer of materials research laboratory, Lewis Institute, Chicago, Ill.; Harold F. Clemmer, Assoc. M. Am. Soc. C. E., engineer of materials, State Highway Department, Springfield, Ill.; Prevost Hubbard, M. Am. Soc. T. M., chemical engineer, the Asphalt Association, 25 West Forty-third Street, New York City; Claude L. McKesson, Assoc. M. Am. Soc. C. E., research engineer, California Highway Commission, Sacramento, Calif.; Horatio S. Mattimore, Assoc. M. Am. Soc. C. E., engineer of tests, State Highway Department, Harrisburg, Pa.

France.—(In collaboration): Messrs. Bouteville, engineer of bridges and roads, attached to the chief of the technical service of public ways and the lighting of the town of Paris, 34 Avenue Rollin, Paris; Vanneufville, engineer of bridges and roads, 98 Quai de la Râpée, Paris.

Great Britain.—M. W. J. Taylor, Esq., O. B. E., M. Inst. C. E., county surveyor, Southampton County Council.

Italy.—Mr. Luigi Torri, of the Technical Bureau of the Milan Municipality.

Monaco.—Dr. Guglielminetti, member of the Permanent International Commission of the Road Congress, Paris.

Switzerland.—(In collaboration): Messrs. R. Schlaepfer, cantonal engineer, Herisau; Dr. P. Schlaepfer, professor at the Federal Polytechnic School at Zurich.

Czechoslovakia.—M. Karel Spacek, engineer and professor at the Technical High School of Prague, Prague-Smichowulice Pavla Svandy, No. 7 n.

SECOND SECTION

CIRCULATION AND WORKING

Fourth Question. Census of Circulation

United States.—(In collaboration): Messrs. Henry R. Trumbower, economist, U. S. Bureau of Public Roads, Washington, D. C.; Thomas R. Agg, M. Am. Soc. C. E., professor of highway economies, Iowa State College, Ames, Iowa; J. Rowland Bibbins, consultant in transportation, Cosmos Club, Washington, D. C.; Arthur H. Blanchard, M. Am. Soc. C. E., professor of highway engineering and highway transportation, University of Michigan, Ann Arbor, Mich; William P. Eno, Eno Foundation, 1771 N Street, Washington, D. C.; Ernest P. Goodrich, M. Am. Soc. C. E., consulting engineer, 15 Park Row, New York City; Laurence I. Hewes, Ph. D., M. Am. Soc. C. E., deputy chief engineer, U. S. Bureau of Public Roads, San Francisco, Calif.; John N. Mackall, M. Am. Soc. C. E., chairman and chief engineer, State Roads Commission, Baltimore, Md.; William A. Van Duzer, M. Am. Soc. C. E., equipment and transport engineer, State Highway Department, Harrisburg, Pa.

France.—Mr. Delemer Léon, chief engineer of bridges and roads, secretary of the first section of the Board of Bridges and Roads, Ministry of Public Works, Paris.

Great Britain.—C. H. Bressey, Esq., C. B. E., F. S. I., chief engineer, Roads Department, Ministry of Transport, London.

Italy.—(In collaboration): Messrs. Ugo Cantalamessa, chief engineer of the Technical Bureau of the Province of Rome; Antonio Albertini, chief engineer of the Technical Bureau of the Province of Modena; Pietro Remondini, chief engineer of the Technical Bureau of the Province of Ravenna.

Low Countries.—(In collaboration): Messrs. G. J. Van den Broek, chief engineer of the "Rykswaterstaat," Surinamestraat, No. 1, The Hague; Dr. J. H. Van Zanten, municipal administrator of the town of Amsterdam, Statistics Office, Hotel de Ville.

Sweden.—Mr. Per Gustav Blidberg, lieutenant au Corps des Ponts et Chaussées, Märten Krakowsgatan, 5 Gothenburg.

Switzerland.—Mr. A. Altweg, cantonal engineer, St. Gallen.

Czechoslovakia.—Mr. Antonin Hlousek, engineer and chief adviser at the Ministry of Public Works, Libenskaulice, No. 453, Prague VII.

Fifth Question. Development and Organization of Towns in the Interest of Traffic

Belgium.—(In collaboration): Messrs. Maertens, managing director of the department of municipal thoroughfares, Agricultural Ministry and Public Works, 3 rue du Méridien, Brussels; Mullis, architectural engineer, chief of the bureau, department of municipal thoroughfares, Agricultural Ministry, 3 rue du Méridien, Brussels; Luyssen, engineer of bridges and roads, 33 Square Gutenberg, Brussels; E. d'Hoop, engineer, director of the technical department of the Brussels Tramways Co., 15 Avenue de la Toison-d'Or, Brussels.

Brazil.—(In collaboration): Messrs. Da Silva Freire, director of public works, Sao Paulo; J. Da Costa Ferreira, assistant director of the public ways, Municipal Prefecture, Rua D. Anna, 26 Rio de Janeiro.

United States.—(In collaboration): Messrs. Frederick L. Olmstead, landscape architect, member advisory committee on physical survey of regional plan of New York City and its environs, Brookline, Mass.; Charles B. Ball, M. Am. Soc. C. E., chief sanitary inspector, Department of Health, Chicago, Ill.; Harland Bartholomew, M. Am. Soc. C. E., engineer, City Planning Commission, St. Louis, Mo.; Frederic A. Delano, Hibbs Building, Washington, D. C.; Frederic H. Fay, M. Am. Soc. C. E., chairman Planning Board of the City of Boston, 200 Devonshire Street, Boston, Mass.; Morris Knowles, M. Am. Soc. C. E., consulting engineer, Pittsburgh, Pa.; Arthur A. Shurtleff, consultant, Metropolitan Planning Division, Commonwealth of Massachusetts and Boston Park Department, Boston, Mass.; Arthur S. Tuttle, M. Am. Soc. C. E., chief engineer, Board of Estimate and Apportionment, New York City; George S. Webster, M. Am. Soc. C. E., consulting engineer, 816 Widener Building, Philadelphia, Pa.; E. P. Goodrich, 15 Park Row, New York City.

France.—Mr. Massard, president of the second commission of the Municipal Board of Paris.

Great Britain.—(In collaboration): Chief Constable A. Bassom, O. B. E., New Scotland Yard, London; J. L. D. Elliot, Esq., C. B., New Scotland Yard, London; H. Vaughan Lanchester, Esq., F. R. I. B. A., 19, Bedford Square, London W. C. 1; G. L. Pepler, Esq., Ministry of Health, London.

Italy.—(In collaboration): Messrs. Massimo Settimi, Technical Bureau of the Rome Municipality; Tognetti, chief engineer at the Technical Bureau of the Municipality of Florence.

Low Countries.—(In collaboration): Messrs. L. N. Holsboer, director of public works of the town of Utrecht, 2 Nieuwe Graht, Utrecht; A. H. Sirks, chief of the municipal police of the town of Rotterdam, Central Police Bureau, Rotterdam.

Sweden.—Mr. Carl Gustav Bergman, captain of Bridges and Roads Corps, Riddarhustorget, 8 Stockholm.

Switzerland.—Mr. E. Bosshard, municipal engineer of the town of Zurich.

Czechoslovakia.—Mr. Posef Prada, chief adviser of the Police Board at Prague, Krokivaulice, No. 6, Prague Smichov.

Sixth Question. Roads Specially Reserved for Motor Cars

Belgium.—(In collaboration): Messrs. Cauterman, chief engineer of the Technical Department of the Province of East Flanders, Ghent; M. De Graer, engineer of the Technical Department of the Province of West Flanders, Furnes.

(Continued on p. 127)

PROCEEDINGS OF HIGHWAY RESEARCH BOARD

Reviewed by R. E. ROYALL, Assistant Highway Engineer, Bureau of Public Roads

THE widespread interest in highway research and the many problems involved which call for specialization in numerous lines, some related and some entirely dissimilar, are illustrated by the Proceedings of the Fifth Annual Meeting of the Highway Research Board of the National Research Council which has recently been issued. A glance through this publication shows that many agencies including the Federal and State Governments, and engineering and economic departments of universities and colleges are working on the various problems. The proceedings have been issued in two parts: Part I containing reports of the special committees; and Part II which is a report of the investigation of the economic value of reinforcement in concrete roads by C. A. Hogentogler.

FACTORS AFFECTING COST OF VEHICLE OPERATION INVESTIGATED

The report of the committee on economic theory of highway improvement contains a résumé of tests made to determine motor-vehicle wind resistance, tire wear, and gasoline consumption. Wind resistance measurements were made in a special wind tunnel at Manhattan, Kans., by L. E. Conrad. He finds that the equation for the wind resistance per square foot of projected area averaged for 14 makes of cars is, $P = 0.00149\ V^{2.14}$, where P is the pressure per square foot in pounds and V is the speed in miles per hour.

Investigations of tire wear have been conducted at the University of Kansas by W. C. McNown and at the State College of Washington by H. J. Dana. In the former experiment a passenger car was operated over various types of surface at a speed of approximately 25 miles per hour and the loss in tire weight owing to wear was determined. The wear indices reported were as follows: Concrete and brick 1.0, Iowa gravel 2.2, chert gravel 7.3, and bituminous macadam (unsealed) 10.6.

In the tests at the State College of Washington, the tire wear in pounds per thousand miles was found to vary from 0.0477 for a light car to 0.1183 for a heavy car, on concrete and bituminous surfaces. For the light car on crushed basalt macadam the wear was 0.2972, whereas for the heavy car on water-worn gravel the wear was 0.6250.

The report on gasoline-consumption tests by Maj. Mark L. Ireland, of the Quartermaster Corps, shows rates of consumption under various conditions ranging from 6.7 to 17.7 miles per gallon for passenger cars and from 2.67 to 7.3 miles per gallon for trucks.

STRUCTURAL DESIGN OF ROADS

The report of the committee on structural design of roads contains some of the most important research developments of the year. Stresses in concrete roads have been investigated by actual field and laboratory tests by the Bureau of Public Roads and on the basis of mathematical theory of elasticity by H. M. Westergaard, of the University of Illinois. Professor Westergaard presents a method of calculating the required thickness of a concrete road slab for a given wheel load if the allowable stresses are assumed. Using the assumed stresses, tables, and diagrams presented in the report, computations may be quickly made which will indicate what additional thickness of concrete is required for an increase in wheel load and what may be saved in thickness by eliminating the heaviest vehicles. Information of this character is particularly valuable in apportioning the cost of highways to different classes of traffic.

The Bureau of Public Roads tests are reported by L. W. Teller, who describes the measurement of stresses in concrete roads, using a compact-recording strain gauge of high magnification. With this instrument it has been possible to study the maximum stress in pavement slabs, the balance of the various cross-sectional designs, the transfer of stress across molded joints and the effect of subgrade conditions. Tests with this instrument have been made in cooperation with the Pennsylvania State highway department and with the highway authorities of Cook County, Ill., while tests using 6-wheel trucks for loading have been conducted at the Arlington Experiment Farm.

W. K. Hatt of Purdue University presented a report on experiments on extensibility of concrete. These experiments were undertaken to determine the factors affecting extensibility, studying first the effect of curing conditions and mesh reinforcement. They have not yet been completed but have progressed to the point where certain well-defined indications can be stated.

Subgrade investigations for the year 1925 by the Bureau of Public Roads were reported by Ira B. Mullis. This report discusses the characteristics of good and poor subgrade soils, the movement of surface and ground water, treatment of wet cuts and of soils having a high capillary potential, and the influence of climate on subgrade conditions.

H. E. Breed, of New York University, presented a summary of tension tests of concrete briquettes reinforced with steel fabric. The object of the tests was to determine the benefit of steel fabric reinforcing during the first seven days after placing when concrete is weakest and has to resist the greatest contraction. Briquettes approximately four times the size of ordinary tension briquettes were used. Among the conclusions it is stated that concrete of the dense mix used, treated as described, reinforced with one-eighth to one-fourth per cent steel fabric, is benefited in tensile strength far more than the percentage of steel used would indicate.

W. D. Somervell, of the North Carolina Highway Commission, described a successful field experiment in which transverse planes of weakness were introduced in a concrete road slab to prevent the formation of transverse cracks elsewhere. At 40-foot intervals, reinforcing was omitted in a strip of paving 1 foot wide and a thin wooden strip 2 inches deep was inserted in the surface. This strip was later removed and the space filled with tar filler. In the 2,000-foot section constructed in this way, no transverse cracks have formed except at the planes of weakness.

C. L. McKesson, of the California Highway Commission, presented a summary of the subgrade treatment experiments at Rio Vista, Calif. His conclusions were as follows:

That soil adulteration with cement or lime compounds is not an efficient or economical method of securing stability in heavy soils.

That the suitability of soil for subgrade purposes, or the merits of various methods of soil treatment can be determined by relatively simple laboratory tests and that expensive field tests can in some cases be avoided by first resorting to a properly conducted laboratory investigation.

That a sand or gravel layer is an efficient and economical method of minimizing damage to pavements resulting from swelling or shrinkage of the subsoil.

CHARACTER AND USE OF ROAD MATERIALS

R. W. Crum, of the Iowa State Highway Commission, reviewed the various investigations of the use of calcium chloride and soluble compounds of calcium chloride base as accelerators in the hardening of concrete. He finds the investigators in substantial accord that the early strength of concrete is increased and also the permanent strength when the hardening material is used in quantities less than 4 per cent of the weight of the cement. Further investigation is needed to formulate rules of practice for varying local conditions and different cements. Such admixtures are also useful to counteract to some extent the low strength resulting from curing at low temperature, but calcium chloride can not be depended upon to protect against freezing.

A review of tests of quick-hardening cements was given by F. C. Lang, of the Minnesota State Highway Department. Such cements are of two classes, high alumina and special Portland cements. Some of the high-alumina cements appear to be resistant to the action of sulphate and alkali water and all investigators agree that both classes give an early high strength. H. S. Mattimore has found that high-alumina cement concrete has compressive and transverse strengths at 24 hours greater than those of Portland cement concrete at 28 days. Mr. Lang gives information from various investigators as to time of set, early strength, quantity of mixing water, and methods of curing which will be valuable to users of these new materials.

B. A. Anderton, of the Bureau of Public Roads, reviewed the progress made during the last year in investigations of bituminous mixtures. Several investigators have brought out that with an increase in bitumen content beyond a certain point there is a rapid decrease in stability. It is the theory of some investigators that the bitumen should be sufficient, or almost sufficient, to fill the voids in the aggregate when the grains are in as close contact with each other as they are in a pavement; but it appears from other tests that maximum stability with most mixtures of the sheet-asphalt type, may be obtained with a proportion of bitumen considerably less than this amount.

Paint for highway traffic lines or zones has come into such general use that there is need for laboratory methods of determining the quality of such paints. H. S. Mattimore, of the Pennsylvania State Highway Department, has made a helpful contribution in this direction through a discussion of physical tests for consistency, spreading rate, hiding power, drying time, light resistance, visibility, and durability.

HIGHWAY TRAFFIC ANALYSIS

The committee on highway traffic analysis presented discussions of the 3-lane, 2-way roadway, traffic analysis, elimination of obstacles impeding the free flow of traffic, and adequate rights of way for future highway development.

The committee concludes that 22 and 24-foot roadways are not needed for two lanes of traffic. Roadways 24 to 30 feet in width are used as 3-lane, 2-way roadways. Due to the impossibility of governing traffic on the middle lane by right-of-way regulations the committee recommends 4-lane roadways where a 2-lane roadway is not adequate.

The discussions of the committee were supplemented by papers by J. G. McKay, of the Bureau of Public Roads, dealing with population and highway traffic and interstate traffic on Federal-aid highways. The former paper discusses population and population trends in relation to present and future highway traffic and gives a brief résumé of the analysis of this phase of the problem in the Cook County transportation survey.

In the paper on interstate traffic on Federal-aid highways Doctor McKay presented figures from various traffic surveys showing the large percentage of interstate travel and pointed out that highways are no longer neighborhood affairs to be discussed in town meeting and to be maintained by local authorities.

HIGHWAY FINANCE

The committee on highway finance substituted for its report the report of the special investigation of urban aspects of the highway finance problem conducted under the auspices of the Highway Research Board by Jacob Viner, of the University of Chicago. This study had for its purpose an examination of those problems connected with the financing of highways which affect most closely the governments and residents of urban communities.

The study deals with three phases of the problem:

1. The special interests of cities and of urban motor-vehicle owners in the highway finance policies and practices of State and county governments.

2. The methods and problems of urban highway finance.

3. The financial aspects of the traffic congestion problem.

HIGHWAY MAINTENANCE

Seven different maintenance problems were studied during the year by subcommittees to which they were assigned and the subcommittee reports were used in formulating the report of the main committee. This report discussed dust prevention and surface treatment of gravel and macadam roads, crack fillers for concrete pavements, snow removal and snow-removal equipment, highway signs, standardized maintenance accounting, relation between age of pavement and its annual maintenance cost, coverings for poorly constructed and disintegrating concrete roads, and a description of an instrument for measuring road roughness.

In discussing the surface treatment of gravel roads it is stated that a season's application of calcium chloride varies in cost from $250 to $300 per mile, as against $300 to $500 per mile for light asphaltic oil. The

opinion is very general that the minimum traffic for which light asphaltic oil or calcium chloride treatment is justified ranges from 300 to 500 vehicles per day, and the minimum traffic justifying a bituminous or mat-forming surface treatment ranges from 500 to 800 vehicles per day.

A survey by the committee indicates that there is considerable variation in practice as to crack fillers for concrete pavements. Some States use asphalt in its various forms, while others use tar. Some require a penetration as low as 35, whereas others require up to 250. Most of the States use coarse or fine sand as covering material, but a few have experimented with other materials. Experiments are now under way in Illinois, Connecticut, Michigan, and California with various combinations of material.

The review of snow-removal activities shows that an increasing mileage is being kept open each year and that improved methods and machinery are being used, but there has been no unusual development in this field.

In discussing maintenance accounting the committee suggests that such accounting should cover quantities of work performed and unit costs as well as purposes, totals, and places of expenditures. It recommends that the standard system of accounting as adopted by the American Association of State Highway Officials be put into operation by all of the States as soon as possible.

The committee feels that the question of type of resurfacing for old and worn concrete roads is of increasing importance. It is not yet ready to offer conclusions, and lists a number of projects which have been resurfaced and which should be studied to determine the best methods.

PROGRESS MADE IN SPECIAL INVESTIGATIONS

S. S. Steinberg, of the Highway Research Board, presented a report on the work that has been done in getting under way the special investigation of the board on the development of earth roads. The objects of the investigation are to coordinate the data already available on the improvement of earth roads and to stimulate further research in order to find an inexpensive road surface to carry intermediate traffic. No field investigations have yet been made, but the material assembled will enable the investigator to study effectively in the field the experiments completed or under way in many sections of the country.

R. W. Crum and Mark Morris, of the Iowa State Highway Commission, presented a progress report on the culvert investigation undertaken by the Highway Research Board. Fourteen States have been visited and 516 installations inspected. The report discusses characteristic types installed and defects observed, with causes.

REINFORCEMENT IN CONCRETE ROADS

Part II of the proceedings contains the report of the investigation of the economic value of reinforcement in concrete roads by C. A. Hogentogler. In this survey a general inspection was made of 5,500 miles of road in a search for plain concrete surfaces which had disintegrated, reinforced surfaces which had failed, and cracks in reinforced concrete pavements of such width as to indicate broken steel. Detailed inspections were made of about 2,000 miles of concrete road in 26 States, including thicknesses of 5 to 10½ inches, ages from 1 to 13 years, subgrades ranging from stable sands to bad clays, all conditions of traffic, and reinforcement ranging from light wire fencing to ⅞-inch-bar mats.

The report includes sketches showing detailed conditions as regards cracks and breakage, photographs, design details, road condition charts, digests of pertinent highway researches and reports of allied investigations furnished by cooperating agencies. In a summary of conclusions 14 points are presented among which are the following:

The amount of cracking and subsequent disintegrating is a function of time; thus, the rate of cracking is a measure of the life of the pavement.

The data show that steel reinforcement reduced the rate of cracking and thus increased the life of the pavement. This applies both to concrete pavements and other pavements laid upon a concrete base.

Crack reduction is more economically accomplished by the use of steel reinforcement than by additional thickness of concrete.

A greater reduction was afforded by small steel members closely spaced than by larger members widely spaced.

Copies of the proceedings may be obtained by addressing the Highway Research Board, National Research Council, Washington, D. C.

(Continued from p. 124)

China.—M. Ouang Hang, engineer of the railways, Paris representative of the Ministry of Communications, Peking.

United States.—(In collaboration): Messrs. Thomas H. MacDonald, Chief, U. S. Bureau of Public Roads, Washington, D. C.; John A. Macdonald, State highway commissioner, Hartford, Conn.; W. G. Sloan, State highway engineer, Trenton, N. J.

France.—(In collaboration): Messrs. E. Chaix, vice president of the A. C. F., president of the Tourist and General Traffic Commission of the A. C. F., director of the National Touring Office; Gaston Raffard, member of the Touring and General Traffic Commission of the A. C. F., 8 Place de la Concorde, Paris.

Great Britain.—Sir Lynden Macassey, K. B. E., M. A., Ll. D., etc., 24 Sloane Gardens, London S. W. 1.

Italy.—(In collaboration): Messrs. Avv. Francesco La Farina, Ministry of Public Works, Rome; Eng. Gaetano D'Alò, director of the inspection department of railways, tramways, and motors, Milan; Marquis Avv. Paolo Sommi-Picenardi, director of the Automobile Club, Milan; Alberto Depetrini, section chief of the Ministry of Public Works, Rome.

Low countries.—(In collaboration): Messrs. D. A. Van Heyst, chief engineer of the "Rykswaterstaat" at The Hague, 121 Bezuidenhout; G. J. Van den Broek, chief engineer of the "Rykswaterstaat," 1 Surinamestraat, The Hague; P. J. Van Woorst Vader, jr., chief engineer of the "Rykswaterstaat," 13 Florapark, Haarlem.

Sweden.—Mr. Adler (Knut Kristian), captain of the Bridges and roads Corps, Linkoeping.

GENERAL SPEAKERS

First question: Engineer Angelo Rampazzi, section president at the Board of Public Works, Rome.

Second question: Engineer Italo Vandone of the Italian Touring Club, Milan.

Third question: Engineer Michelangelo Böhm, 45 Via De Amicis, Milan.

Fourth question: Engineer Luigi Frosali, chief engineer of the Technical Bureau of the Province of Florence.

Fifth question: Engineer Cesare Albertini, of the Technical Bureau of the Milan Municipality.

Sixth question: Grand Uff. Michele Carlo Isacco, managing director of traffic and ports, Ministry of Public Works, Rome.

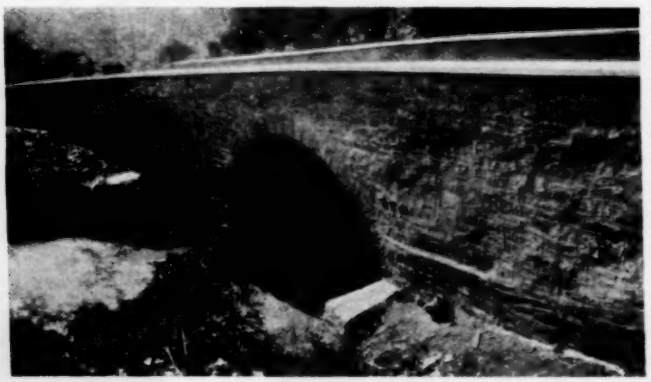
VIRGINIA BUILDING DEMONSTRATION ROAD

HISTORIC BULL RUN BATTLEFIELD THE SITE OF IMPORTANT HIGHWAY INVESTIGATIONS

Reported by C. A. Hogentogler, Highway Engineer, U. S. Bureau of Public Roads

A DEMONSTRATION highway from which it is expected to obtain information comparable in value and importance with that produced by the Bates Road and Pittsburg (Calif.) tests and the experiments of the Bureau of Public Roads at Arlington, Va., is now under construction between Fairfax and Warrenton, Va. The road, which is being built by the Virginia Highway Commission under the directon of Henry G. Shirley, chairman, and C. S. Mullen, chief engineer, of the commission, is a Federal-aid project. It traverses the historic Bull Run battlefield and the famous bridge over the run still may be seen by visitors to the demonstration road.

The new demonstration, unlike the previous experimental roads, is not intended as a test of road design or of the relative value of different surfacing materials. The Virginia standard 8–6–8 concrete section, which is used on the major portion of the road, is not in question. Instead the type of information sought concerns



THE FAMOUS STONE BRIDGE CROSSING BULL RUN

a number of questions not covered by the previous tests and relating principally to the influence of the subgrade, the effect of admixtures of various sorts, of the kind and quantity of reinforcement, of various finishing methods, and other details of construction. In general, the type of information sought concerns the economy of various common practices in concrete construction, especially the various measures employed to prevent cracking and breaking and promote the smoothness of the surface.

In its length of 9 miles the road provides opportunity for the study of the effect of the following variables:

1. *The subgrade.*—Seven different types of soil are represented in the natural subgrade and thin courses of stone screenings and both single and double layers of tar paper have been used as coverings in certain sections.

2. *Construction joints and dividing planes.*—Expansion and center joints are used in only one section. Construction joints are placed at noon and at night. Longitudinal dividing planes have been used in two sections, in one of which transverse dividing planes have also been used. These planes of weakness are formed by installation of a patented type of separating strip about 2½ inches deep. With the exception of the section containing both longitudinal and transverse dividing planes, which is laid to a uniform thickness of 7 inches, the Virginia design of 8–6–8 pavement, 18 feet wide, was used in all sections.

3. *Aggregate, cement, and mix.*—The same sand and crushed stone are used throughout the work. Two well-known brands of cement have been used, and the mix is either 1 : 2½ : 3½ or 1 : 2 : 4.

4. *Admixtures.*—The three admixtures used are hydrated lime, 5 and 8 per cent; Celite, 3 per cent; and calcium chloride, 2 per cent; all incorporated.

5. *Types of construction.*—The three types of construction employed are plain concrete, vibrolithic concrete, and reinforced concrete. Both single and double layers of welded steel fabric, bar mats, and expanded metal are used in the latter.

6. *Finishing and curing.*—Part of the road is being finished by hand methods. The remainder is to be machine finished, using both Ord and Lakewood finishing machines. With the exception of the section containing calcium chloride, all sections are to be cured alike by covering with wet earth for 14 days.

EXPERIMENTAL WORK

The road on which the demonstration is being conducted is strictly a service highway constructed under State supervision with convict labor. It will not be subjected to accelerated traffic.

The Bureau of Public Roads is cooperating in the experimental work which includes studies of the subgrade, the concrete materials, and the effect of construction operations. The nature of the investigations is briefly as follows:

1. *Material investigation.*—This work, which is carried on at the Arlington Experiment Farm, includes tests of specimens in which either the sand, cement, or stone is varied, and tests, at various ages, of beams made of the same mixes and containing the same admixtures as the road sections. Routine tests and special expansion and contraction observations are being made in the Washington laboratories of the bureau.

2. *Test cylinders.*—Test cylinders made during construction are being cured alongside of the road under conditions as nearly as possible identical with the road slab. The position of batches from which the cylinders are made is marked so that cores can be drilled later. This will allow a definite comparison to be made between the strengths of cores and cylinders from the same batch.

3. *Surveys and construction observations.*—A complete subgrade survey was made prior to the beginning of construction in the course of which observations of drainage conditions were taken and samples of soil were procured for testing in the laboratory. Subsequent inspections of soil conditions have been made after heavy rains.

Observers stationed on the work are keeping accurate records of all occurrences and practices which might influence the condition of the pavement. Atmospheric conditions, temperature and humidity, and the slump of the concrete are recorded hourly. The time of pouring each batch and the time it is finished and covered is kept accurately and the position of the batch is carefully platted with identifying station numbers indicated. This provides an efficiency record which shows the variation in the intervals between the three important stages.

Condition surveys of the surface are made before the wet earth covering is placed and after it is removed; and all of the data mentioned are plotted on final record sheets together with the grade and alignment of the road. Future surveys will be made to determine how the surface condition is influenced by the various factors.

4. *Observations of surface smoothness.*—After the earth covering is removed the relative smoothness of the various sections will be determined by the use of a 16-wheel profilometer. The effect of the surface condition on truck wheel impact will be measured by means of accelerometers attached to trucks; and the effect on the truck body will be measured with a recording roughometer.

Information with regard to the surface smoothness and relative first costs of the various sections will be available immediately. The influence of the various other factors on the condition of the surface can, naturally, be learned only after the road has been in service a sufficient length of time to develop defects.

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS

Applicants are urgently requested to ask only for those publications in which they are particularly interested. The Department can not undertake to supply complete sets nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Department's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furnish publications free.

ANNUAL REPORT

Report of the Chief of the Bureau of Public Roads, 1924.
Report of the Chief of the Bureau of Public Roads, 1925.

DEPARTMENT BULLETINS

No. 105. Progress Report of Experiments in Dust Prevention and Road Preservation, 1913.
*136D. Highway Bonds. 20c.
220D. Road Models.
257D. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
*314D. Methods for the Examination of Bituminous Road Materials. 10c.
*347D. Methods for the Determination of the Physical Properties of Road-Building Rock. 10c.
*370D. The Results of Physical Tests of Road-Building Rock. 15c.
386D. Public Road Mileage and Revenues in the Middle Atlantic States, 1914.
387D. Public Road Mileage and Revenues in the Southern States, 1914.
388D. Public Road Mileage and Revenues in the New England States, 1914.
390D. Public Road Mileage and Revenues in the United States, 1914. A Summary.
407D. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915.
*463D. Earth, Sand-Clay, and Gravel Roads. 15c.
*532D. The Expansion and Contraction of Concrete and Concrete Roads. 10c.
*537D. The Results of Physical Tests of Road-Building Rock in 1916, Including all Compression Tests. 5c.
*583D. Reports on Experimental Convict Road Camp, Fulton County, Ga. 25c.
*660D. Highway Cost Keeping. 10c.
*670D. The Results of Physical Tests of Road-Building Rock in 1916 and 1917. 5c.
*691D. Typical Specifications for Bituminous Road Materials. 10c.
*724D. Drainage Methods and Foundations for County Roads. 20c.
*1077D. Portland Cement Concrete Roads. 15c.
*1132D. The Results of Physical Tests of Road-Building Rock from 1916 to 1921, Inclusive. 10c.
1216D. Tentative Standard Methods of Sampling and Testing Highway Materials, adopted by the American Association of State Highway Officials and approved by the Secretary of Agriculture for use in connection with Federal-aid road construction.
1259D. Standard Specifications for Steel Highway Bridges, adopted by the American Association of State Highway Officials and approved by the Secretary of Agriculture for use in connection with Federal-aid road work.
1279D. Rural Highway Mileage, Income and Expenditures, 1921 and 1922.

DEPARTMENT CIRCULARS

No. 94C. TNT as a Blasting Explosive.
331C. Standard Specifications for Corrugated Metal Pipe Culverts.

MISCELLANEOUS CIRCULARS

No. 60M. Federal Legislation Providing for Federal Aid in Highway Construction.
62M. Standards Governing Plans, Specifications, Contract Forms, and Estimates for Federal Aid Highway Projects.

FARMERS' BULLETINS

No. *338F. Macadam Roads. 5c.
*505F. Benefits of Improved Roads. 5c.

SEPARATE REPRINTS FROM THE YEARBOOK

No. *727Y. Design of Public Roads. 5c.
*739Y. Federal Aid to Highways, 1917. 5c.
*849Y. Roads. 5c.
914Y. Highways and Highway Transportation.

OFFICE OF PUBLIC ROADS BULLETIN

No. *45. Data for Use in Designing Culverts and Short-span Bridges. (1913.) 15c.

OFFICE OF THE SECRETARY CIRCULARS

No. 49. Motor Vehicle Registrations and Revenues, 1914.
59. Automobile Registrations, Licenses, and Revenues in the United States, 1915.
63. State Highway Mileage and Expenditures to January 1, 1916.
*72. Width of Wagon Tires Recommended for Loads of Varying Magnitude on Earth and Gravel Roads. 5c.
73. Automobile Registrations, Licenses, and Revenues in the United States, 1916.
161. Rules and Regulations of the Secretary of Agriculture for Carrying out the Federal Highway Act and Amendments Thereto.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH

Vol. 5, No. 17, D–2. Effect of Controllable Variables Upon the Penetration Test for Asphalts and AsphaltCements.
Vol. 5, No. 19, D–3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 20, D–4. Apparatus for Measuring the Wear of Concrete Roads.
Vol. 5, No. 24, D–6. A New Penetration Needle for Use in Testing Bituminous Materials.
Vol. 10, No. 5, D–12. Influence of Grading on the Value of Fine Aggregate Used in Portland Cement Concrete Road Construction.
Vol. 11, No. 10, D–15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.

*Department supply exhausted.

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

STATUS OF FEDERAL AID HIGHWAY CONSTRUCTION

AS OF

JULY 31, 1926

STATES	FISCAL YEARS 1917-1926			FISCAL YEAR 1927									BALANCE OF FEDERAL AID FUND AVAILABLE FOR NEW PROJECTS	STATES
	PROJECTS COMPLETED PRIOR TO JULY 1, 1926			PROJECTS COMPLETED SINCE JUNE 30, 1926			*PROJECTS UNDER CONSTRUCTION			PROJECTS APPROVED FOR CONSTRUCTION				
	TOTAL COST	FEDERAL AID	MILES	TOTAL COST	FEDERAL AID	MILES	ESTIMATED COST	FEDERAL AID ALLOTTED	MILES	ESTIMATED COST	FEDERAL AID ALLOTTED	MILES		
Alabama	$ 18,226,411.34	$ 8,725,985.09	1,298.3	$ 1,033,289.73	$ 492,916.35	75.7	$ 4,036,643.28	$ 1,865,385.81	131.4	$ 208,862.54	$ 104,431.27	11.5	$ 3,160,736.48	Alabama
Arizona	10,949,878.25	5,863,772.35	729.8				1,401,980.83	945,372.27	81.4	339,708.89	236,515.53	26.3	2,571,588.85	Arizona
Arkansas	18,364,544.50	7,666,698.35	1,323.0	59,066.03	29,533.01	5.1	4,664,865.94	2,216,118.50	303.7	706,048.44	348,326.76	54.9	1,345,127.38	Arkansas
California	27,142,596.90	13,003,592.30	1,058.0				11,873,095.16	5,790,115.15	320.3	191,797.75	110,673.41	0.5	3,168,434.17	California
Colorado	13,905,904.64	7,127,288.18	745.0	439,200.74	236,115.36	8.2	4,044,755.65	1,972,893.36	207.5	769,494.53	361,022.34	35.1	2,628,492.75	Colorado
Connecticut	5,414,567.19	2,100,585.80	117.1				3,867,110.97	1,019,568.03	54.6	862,699.27	327,521.25	8.9	886,005.92	Connecticut
Delaware	4,918,052.29	1,781,665.60	124.3				1,115,536.81	470,577.90	28.2	623,535.35	218,310.90	15.7	3,503.60	Delaware
Florida	3,832,680.26	1,624,362.32	132.9	420,473.69	208,262.41	20.9	9,358,343.27	4,362,418.06	258.9	241,489.11	119,798.25		1,570,112.96	Florida
Georgia	24,791,206.97	11,664,237.86	1,794.0	551,256.86	274,533.76	30.8	11,872,496.51	5,829,003.86	630.0	1,240,213.28	557,295.51	24.6	106,892.02	Georgia
Idaho	11,081,198.14	5,882,112.70	724.7	254,585.56	130,664.38	6.9	2,737,287.60	1,663,337.23	155.8	1,056,756.72	616,474.67	90.3	267,038.02	Idaho
Illinois	44,116,611.86	20,619,995.74	1,377.7	2,012,307.84	980,960.66	68.1	5,230,338.91	2,508,907.68	180.6	814,171.32	378,771.83	25.8	5,343,562.15	Illinois
Indiana	16,949,425.87	8,172,126.19	534.3	603,411.29	295,697.26	18.4	18,501,800.32	8,713,519.50	528.4	281,117.68	140,558.84	7.2	882,454.21	Indiana
Iowa	29,062,375.40	11,926,302.10	2,114.8	132,077.36	66,038.67	9.9	11,114,136.87	5,351,462.04	705.6	3,160,525.11	1,442,228.21	142.4	699,531.98	Iowa
Kansas	32,826,601.64	12,590,489.25	1,160.6	455,951.75	202,404.07	39.6	11,901,412.35	4,644,543.56	651.4	1,833,784.87	670,215.00	132.9	1,356,759.12	Kansas
Kentucky	20,737,706.10	8,492,082.26	758.3	307,209.39	106,386.83	6.3	5,556,069.73	2,669,005.95	293.5	95,483.33	47,741.66	3.6	1,897,592.31	Kentucky
Louisiana	13,830,592.68	6,144,739.99	1,065.9				3,448,051.45	1,672,702.16	161.2	1,118,622.37	505,003.13	37.6	949,962.72	Louisiana
Maine	8,747,552.76	4,192,507.39	303.6				2,364,417.16	854,849.24	67.3	1,446,337.89	607,067.98	50.0	810,403.39	Maine
Maryland	10,924,943.10	5,112,991.22	423.3				513,398.28	252,643.43	30.8	1,287,472.78	538,920.86	57.6	80,501.49	Maryland
Massachusetts	18,353,757.71	6,657,260.62	374.5				4,567,049.89	1,229,662.38	61.1	944,487.76	247,578.55	14.5	1,974,224.61	Massachusetts
Michigan	26,997,240.78	11,827,052.30	963.0	215,575.91	103,606.96	7.6	11,169,960.39	5,102,817.17	295.2	173,599.00	81,626.50	11.2	3,227,262.07	Michigan
Minnesota	37,170,985.96	15,586,116.56	3,181.9	663,725.36	300,359.07	66.9	9,100,131.01	3,431,500.00	524.3	443,985.90	31,000.00	11.1	242,804.37	Minnesota
Mississippi	15,146,088.52	7,414,534.10	1,129.0	82,987.42	40,629.00	6.9	6,988,798.36	3,463,229.63	380.3	1,705,272.78	784,437.54	80.0	425,187.73	Mississippi
Missouri	28,989,166.92	13,736,014.85	1,543.2	821,068.97	383,099.04	25.8	19,820,709.91	7,900,913.06	841.7	1,056,788.43	465,838.49	19.3	400,570.56	Missouri
Montana	11,400,983.81	6,333,465.89	1,054.9	94,415.49	60,088.27	2.0	1,663,293.14	1,138,296.07	130.8	1,784,353.74	1,353,224.13	149.5	4,539,810.64	Montana
Nebraska	11,533,401.62	5,474,202.52	1,768.3	96,921.54	48,218.16	15.3	13,380,938.73	6,558,392.03	1,366.0	1,279,000.83	613,900.31	126.4	1,940,521.98	Nebraska
Nevada	7,558,195.51	5,130,934.59	538.8	660,130.91	574,971.17	65.1	2,785,464.77	2,392,400.87	321.8	13,387.17	11,743.22		685,165.15	Nevada
New Hampshire	4,992,556.60	2,377,480.07	237.6				948,617.15	437,536.16	28.7	405,722.18	182,933.16	10.0	171,573.59	New Hampshire
New Jersey	16,346,301.01	5,098,342.21	290.3	156,206.43	63,485.76	4.0	6,823,899.73	2,503,716.67	30.9	2,028,186.61	431,160.00	28.7	370,715.36	New Jersey
New Mexico	12,404,337.77	7,339,657.38	1,427.0				1,457,040.48	970,998.85	100.4	935,041.99	661,614.90	65.2	2,000,114.84	New Mexico
New York	43,224,279.79	17,911,957.19	1,197.0	1,275,861.14	487,774.68	28.9	31,802,920.00	8,721,902.70	553.9	9,965,403.00	2,181,550.00	133.4	4,742,010.43	New York
North Carolina	27,009,419.47	11,177,337.94	1,257.9				8,035,569.06	3,484,782.13	190.1	635,619.50	317,809.75	26.1	737,276.18	North Carolina
North Dakota	12,313,311.40	6,031,859.78	2,193.1	33,059.36	16,529.68		6,147,730.12	3,151,787.38	888.1	2,781,831.35	1,502,393.13	277.9	46,089.09	North Dakota
Ohio	47,699,532.90	17,371,787.03	1,364.1	558,568.83	257,865.98	25.5	11,295,034.17	4,348,790.47	335.9	3,887,394.67	1,427,033.34	111.4	2,326,319.18	Ohio
Oklahoma	26,247,950.33	13,159,999.16	1,178.9	38,958.17	19,233.78	5.2	2,852,788.00	1,334,877.48	92.2	877,244.37	418,579.81	71.2	1,127,096.84	Oklahoma
Oregon	17,027,878.42	8,593,214.79	939.2	112,462.11	60,931.58	5.9	3,191,801.52	1,750,354.69	120.4	409,330.64	237,616.61	22.1	237,229.33	Oregon
Pennsylvania	61,366,150.80	21,560,732.04	1,188.8				25,913,665.91	7,325,756.54	629.6	2,919,535.07	933,509.06	68.4	1,518,783.36	Pennsylvania
Rhode Island	3,988,616.09	1,558,829.06	86.7				1,531,802.80	427,155.00	28.8	485,392.16	124,365.00	8.3	557,219.94	Rhode Island
South Carolina	15,020,639.90	6,766,322.93	1,481.9	388,144.47	152,702.67	34.7	5,855,691.37	2,754,874.76	205.6	362,099.99	114,921.58	19.3	12,702.06	South Carolina
South Dakota	17,468,373.19	8,603,826.97	2,161.2	261,269.44	130,634.71	67.0	3,585,246.43	1,806,308.75	603.7	501,057.09	269,552.46	99.7	356,467.11	South Dakota
Tennessee	21,624,631.57	10,276,584.02	780.0				7,850,214.11	3,673,669.06	263.9	1,198,242.23	518,210.12	19.0	912,127.61	Tennessee
Texas	69,183,673.48	27,440,264.72	4,920.2	345,850.83	153,965.47	47.9	18,339,531.39	8,100,493.13	859.5	2,959,406.68	1,334,962.53	66.7	3,576,755.15	Texas
Utah	8,253,178.03	5,096,440.68	546.4				1,707,708.64	1,291,288.39	154.0	848,406.31	646,544.22	56.8	782,505.71	Utah
Vermont	4,242,042.64	2,017,699.51	134.5				1,941,881.25	764,535.39	36.1	161,450.52	41,736.47	2.9	444,535.63	Vermont
Virginia	21,990,249.44	10,385,728.11	1,005.5	373,701.36	166,360.34	10.2	6,052,610.04	2,647,371.87	175.0	664,784.79	245,118.85	18.8	56,934.83	Virginia
Washington	17,078,511.63	7,782,909.46	668.6				3,309,677.73	1,653,600.00	41.0	1,250,203.66	453,000.00	50.4	256,266.54	Washington
West Virginia	9,473,716.44	4,141,082.65	392.9	457,126.16	193,696.41	12.4	4,805,344.41	1,869,689.67	124.7	1,665,915.01	754,239.62	62.8	393,822.65	West Virginia
Wisconsin	24,856,508.19	10,392,705.73	1,592.1				7,892,348.60	3,796,814.62	357.9	814,717.03	393,743.00	57.8	2,855,551.65	Wisconsin
Wyoming	10,928,302.56	6,040,887.05	1,133.5	341,141.32	218,189.00	48.0	2,481,191.35	1,564,084.02	189.4	215,935.78	150,342.81	49.7	592,771.19	Wyoming
Hawaii							1,050,897.93	312,635.18	15.9				787,517.82	Hawaii
TOTALS	966,692,834.36	426,178,703.58	52,526.6	13,246,004.43	6,455,854.47	769.2	347,941,139.49	148,512,656.64	14,329.0	59,652,449.37	24,261,152.56	2,462.4	65,366,632.75	TOTALS

* Includes projects reported completed (final vouchers not yet paid) totaling: Estimated cost $ 84,983,783.06 Federal aid $ 36,689,471.37 Miles 3,228.5